

Embedded Open Source Summit 2024

Whac-A-Mole with DTS Validation in the Linux Kernel

Krzysztof Kozłowski, [Linaro](#)
krzysztof.kozlowski@linaro.org
[@krzk@social.kernel.org](https://social.kernel.org/@krzk)



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 - Do you know it covers also Google Tensor SoC in Google Pixel 6 phone?
 - I am also one of most active contributors to the Linux kernel
- What this talk is going to be about?
 - Short introduction about DTS and Devicetree schema
 - Why am I working on this?
 - Quick look on the progress (aka “Why Whac-A-Mole”)
 - How did the warning fixing go?
 - Was the effort worthwhile? What are the benefits of doing these things right?

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Devicetree Sources and Bindings

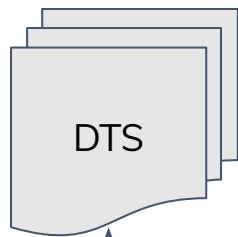
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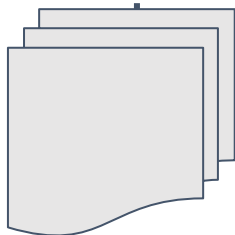
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- Devicetree bindings describe the rules how DTS should be constructed
 - Not describing Linux drivers
 - Documenting the interface for different implementations
- Devicetree schema (DT schema) is the new bindings format which allows:
 - Validation of the bindings itself against meta-schema
 - **Validation of the DTS against bindings** <- that's what this talk is about

Devicetree Sources, Bindings and DT Schema

Devicetree sources

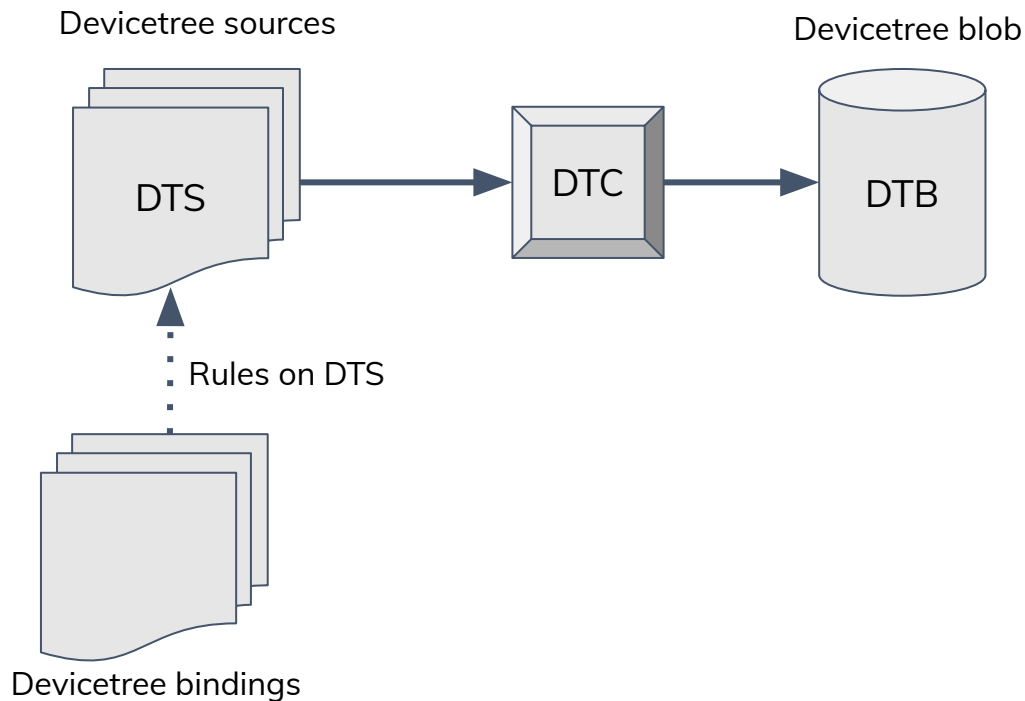


Rules on DTS

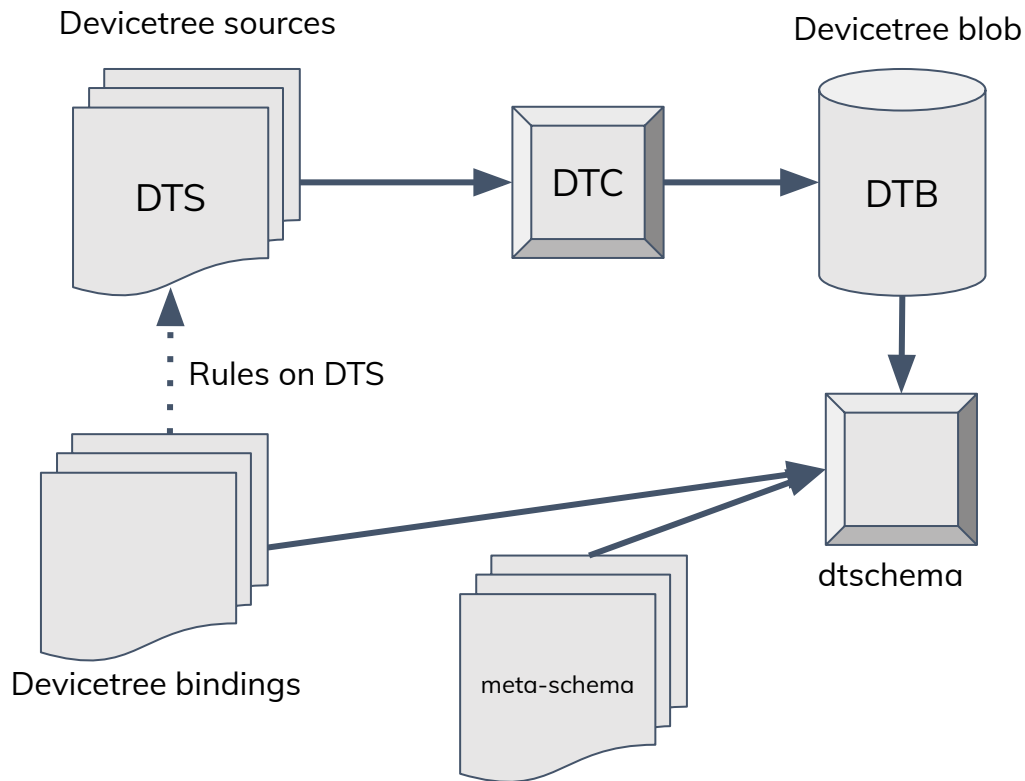


Devicetree bindings

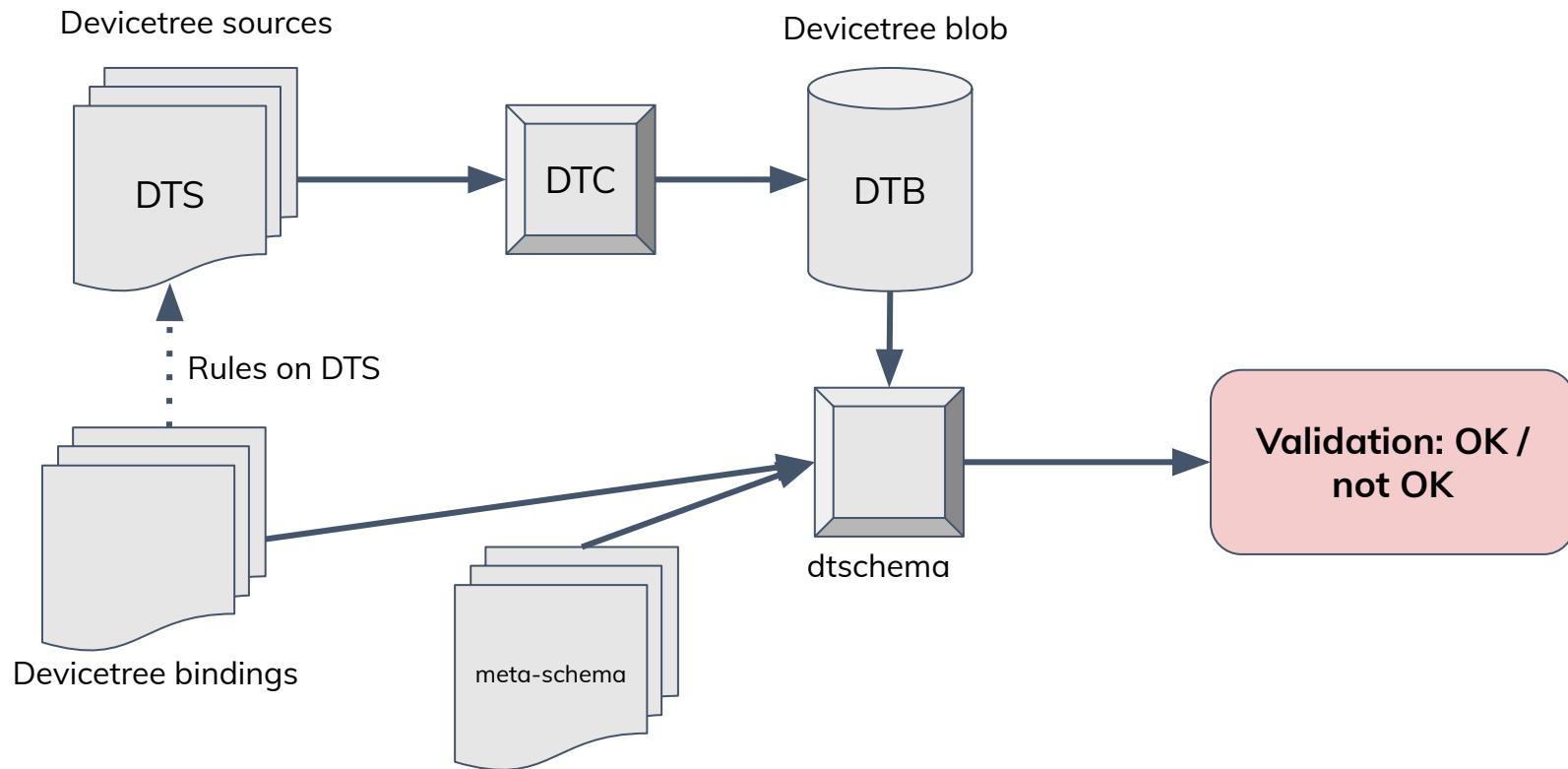
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- In Linux kernel v6.8:
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 - ~64 DTSO files, which are the overlays
 - ~3900 DT bindings files in DT schema format (YAML)
 - This does not map 1-to-1 to supported hardware, because usually one binding describes multiple devices
 - Still ~1500 DT bindings in TXT

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- Later I joined Linaro and joined effort to improve the Qualcomm SoC DTS

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 - That is v5.3 Linux kernel
- I worked primarily on Samsung Exynos platform to make my maintainer life easier
- In 2022 I joined Linaro and started doing the same on Qualcomm platform
 - My work starts with v5.18 Linux kernel

Platforms and Methodology

Methodology

- Comparison between validation warnings seen on DTS from v5.3, v5.10, v5.18, v6.2, v6.5 and v6.8 Linux kernels
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- All tests were done on v6.8 kernel with checking out given DTS (v5.3, v5.10, etc)
 - Short: Used new tools on old DTS
 - With dtschema v2024.2

Tested Platforms

- Due to my particular interests, I did not validate all possible architectures
 - ARC, MIPS, PowerPC: not much work is happening towards fixing any warnings
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 - ARM64, configs:
 - defconfig: almost all ARMv8/v9 targets
 - exynos: Samsung Exynos SoC + Tesla FSD SoC + Google Tensor SoC
 - Even though it is called “Exynos”
 - qcom: Qualcomm ARMv8/v9 SoCs

Number of DTS Targets

- I mentioned before v6.8 kernel has ~2900 DTS files

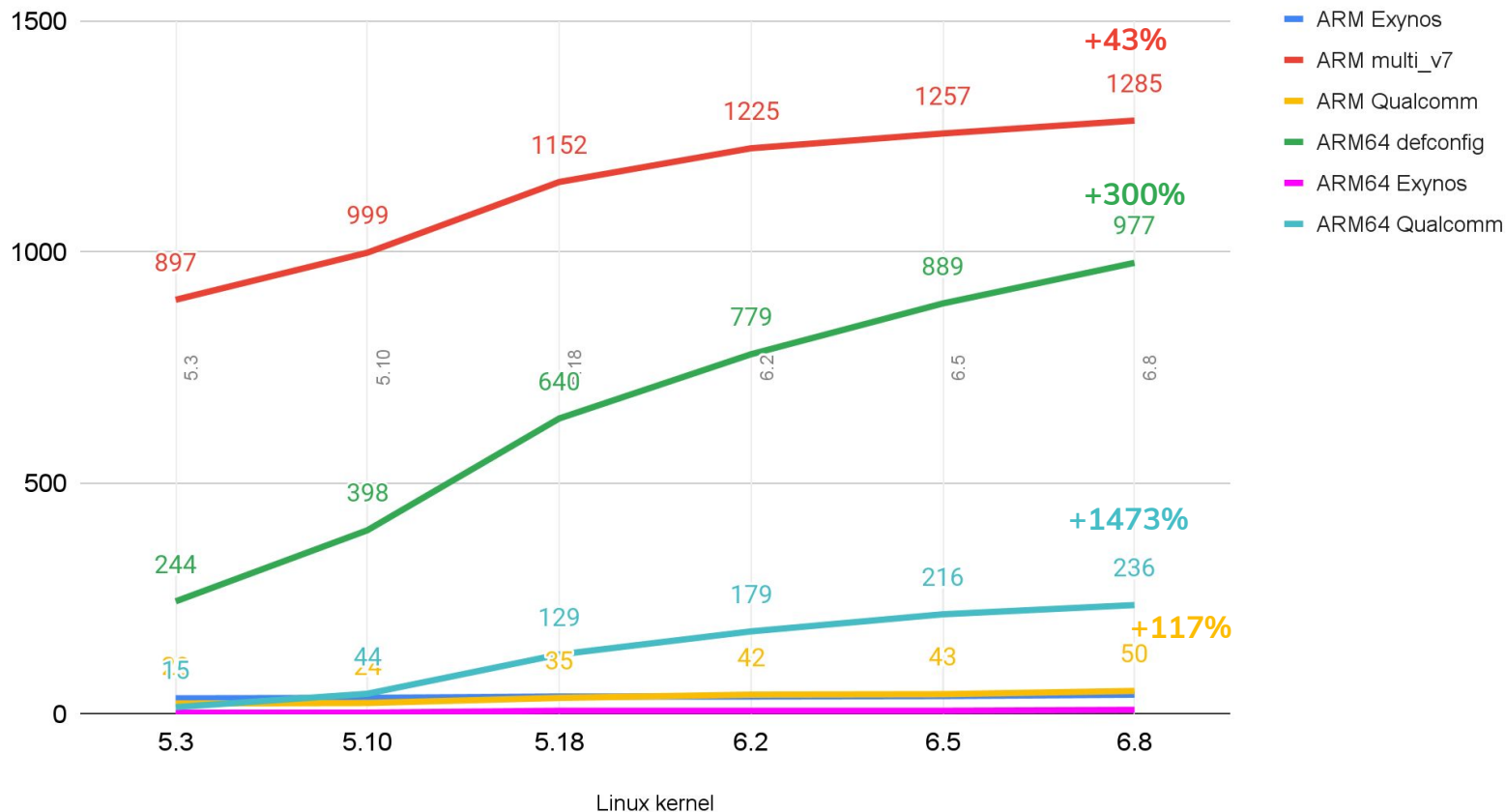
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- Why Makefile DTB? Because that's what DTC (compiler) and DT schema evaluate

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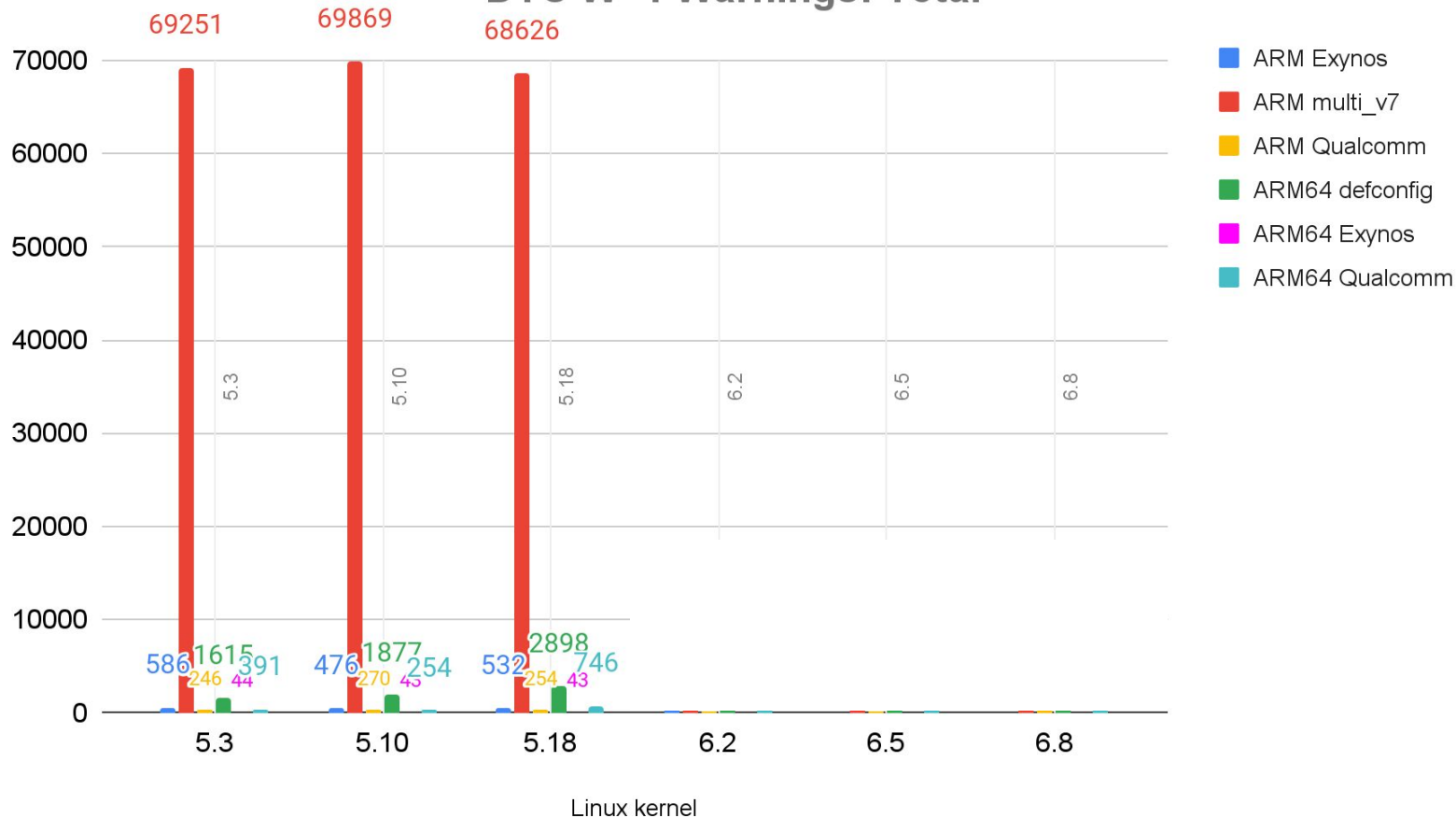
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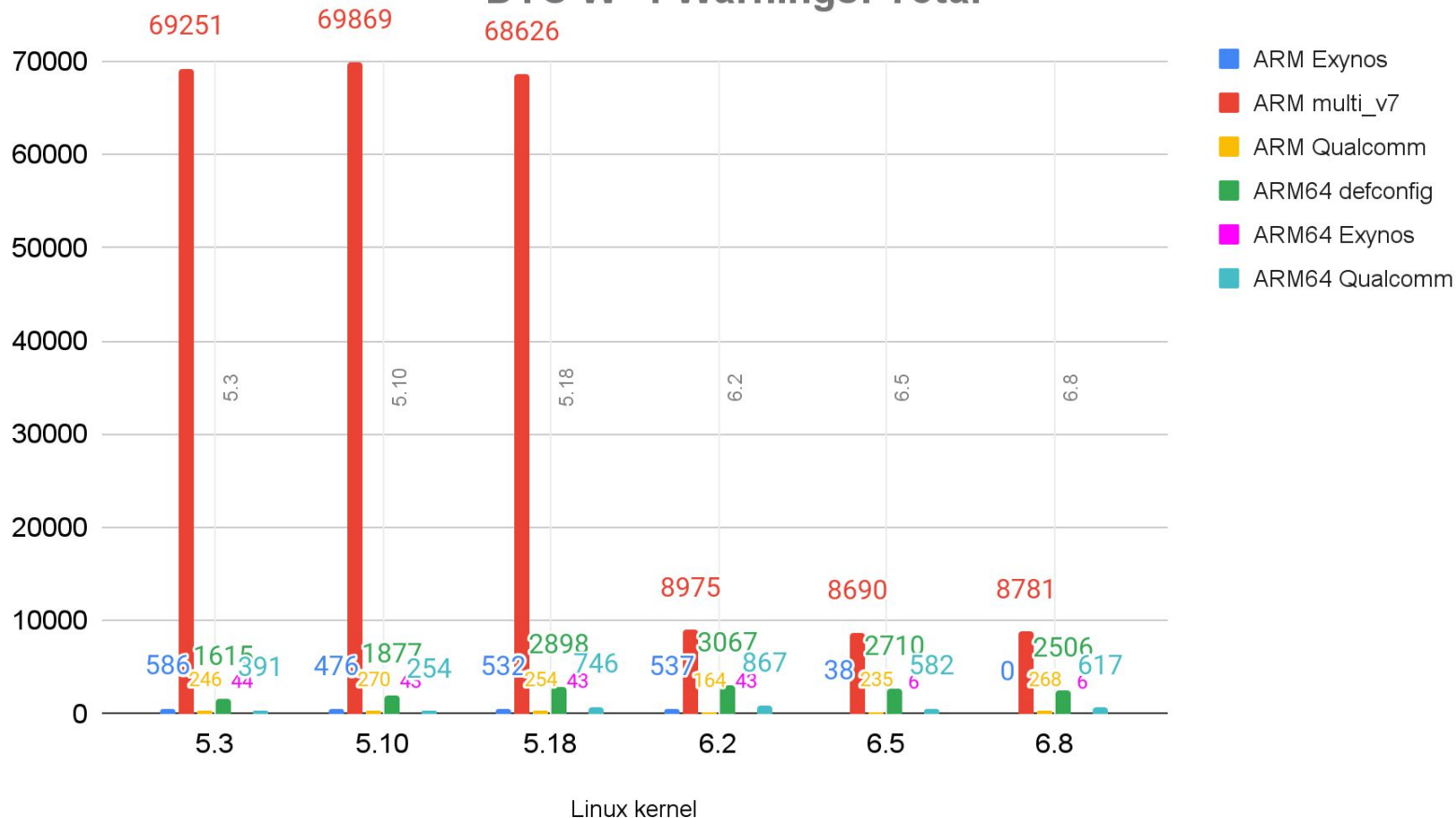
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- Therefore I will cover it just briefly and instead the talk focuses on warnings produced by validation of DTS against DT schema

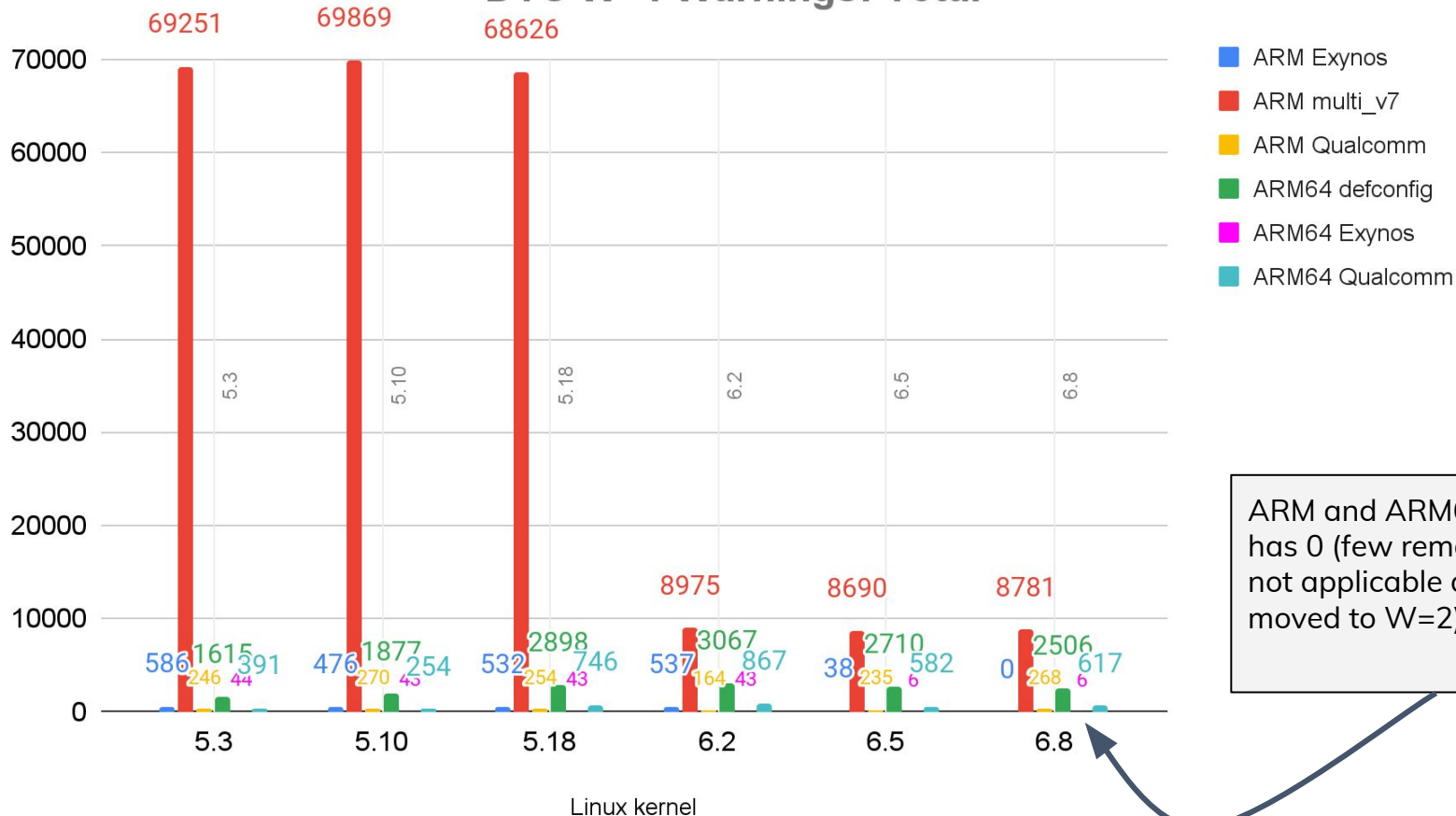
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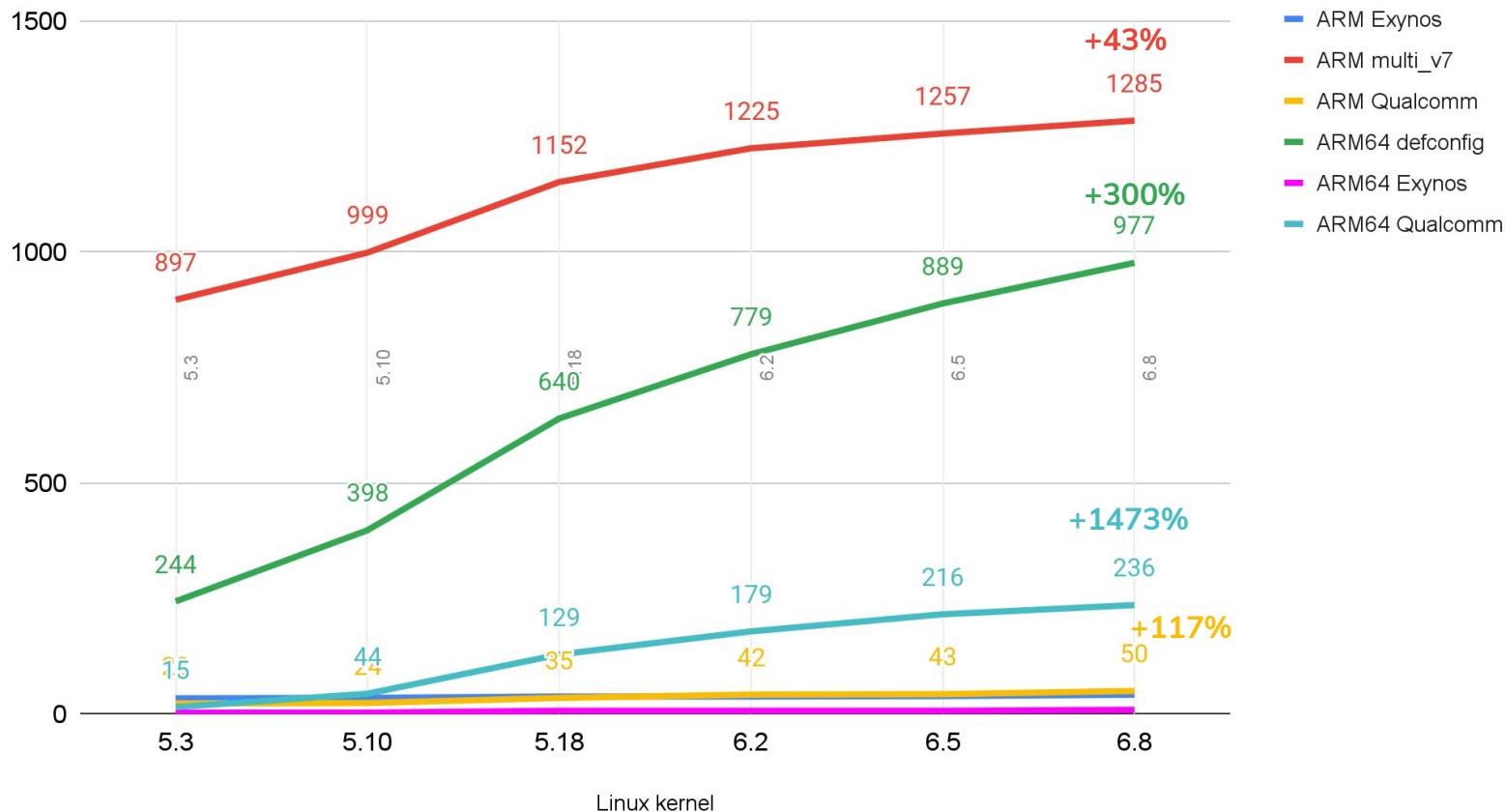


DTC W=1 Warnings: Total



ARM and ARM64 Exynos has 0 (few remaining are not applicable and moved to W=2)

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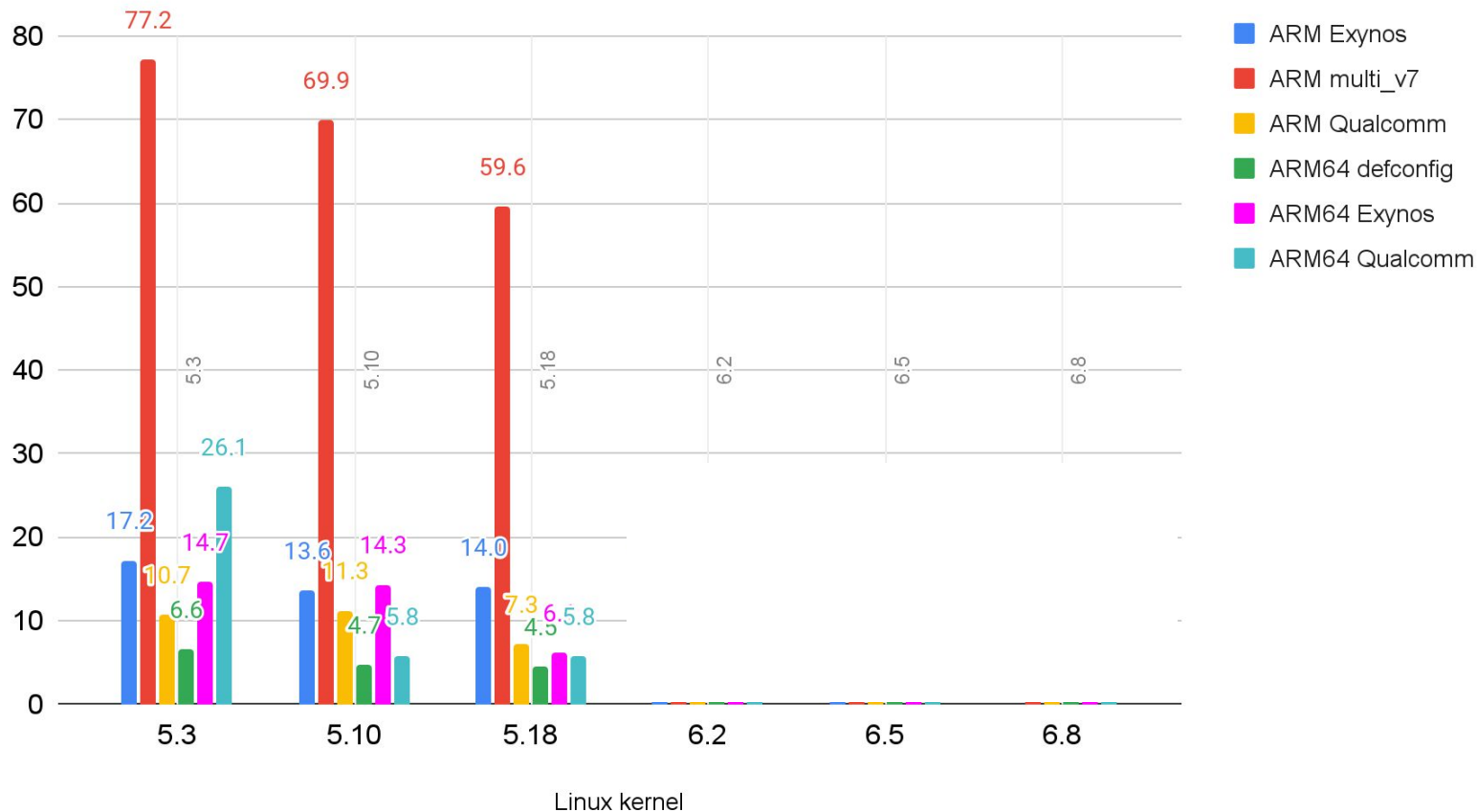
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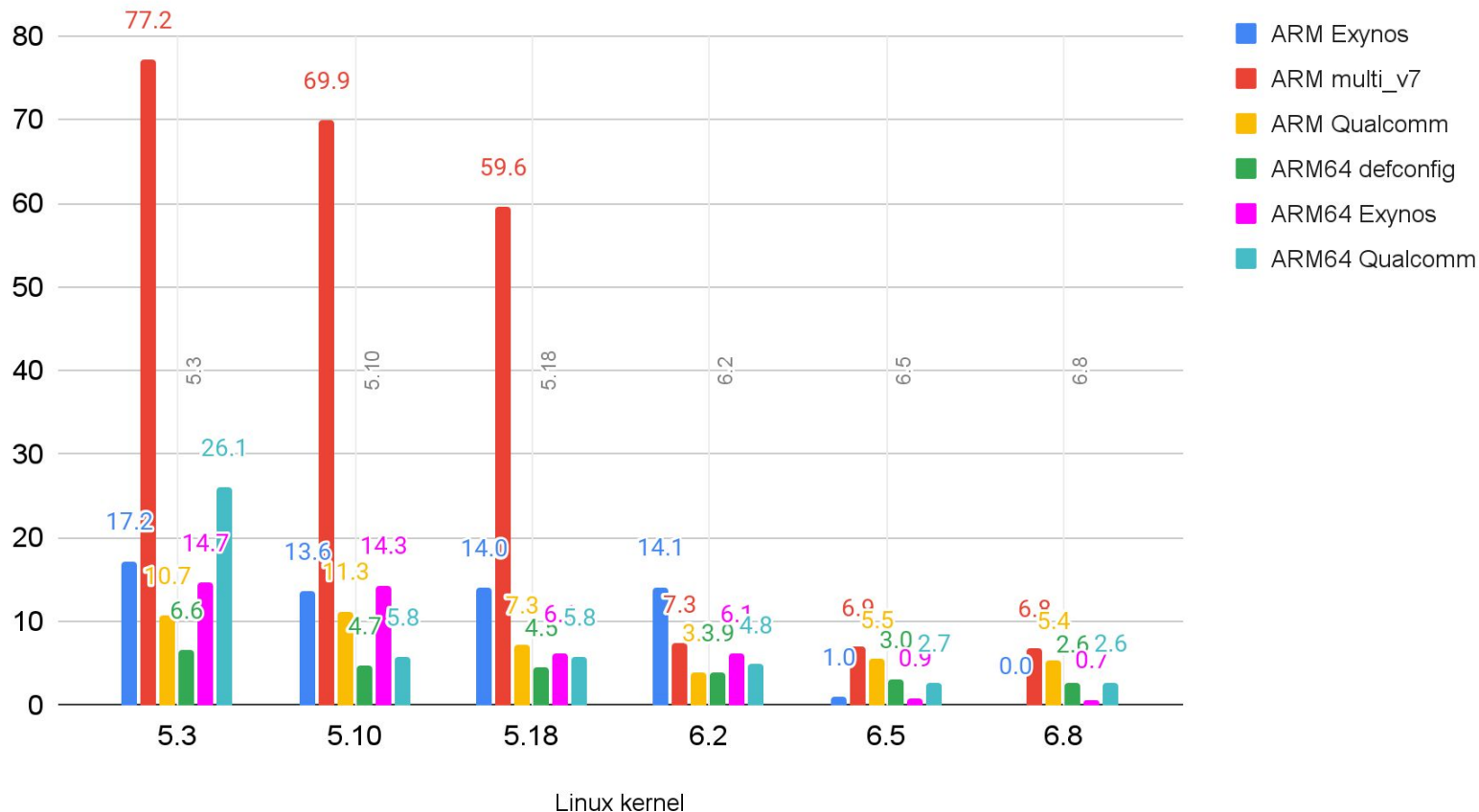
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- More interesting metric:
 - $(\text{Number of warnings}) / (\text{Number of targets})$

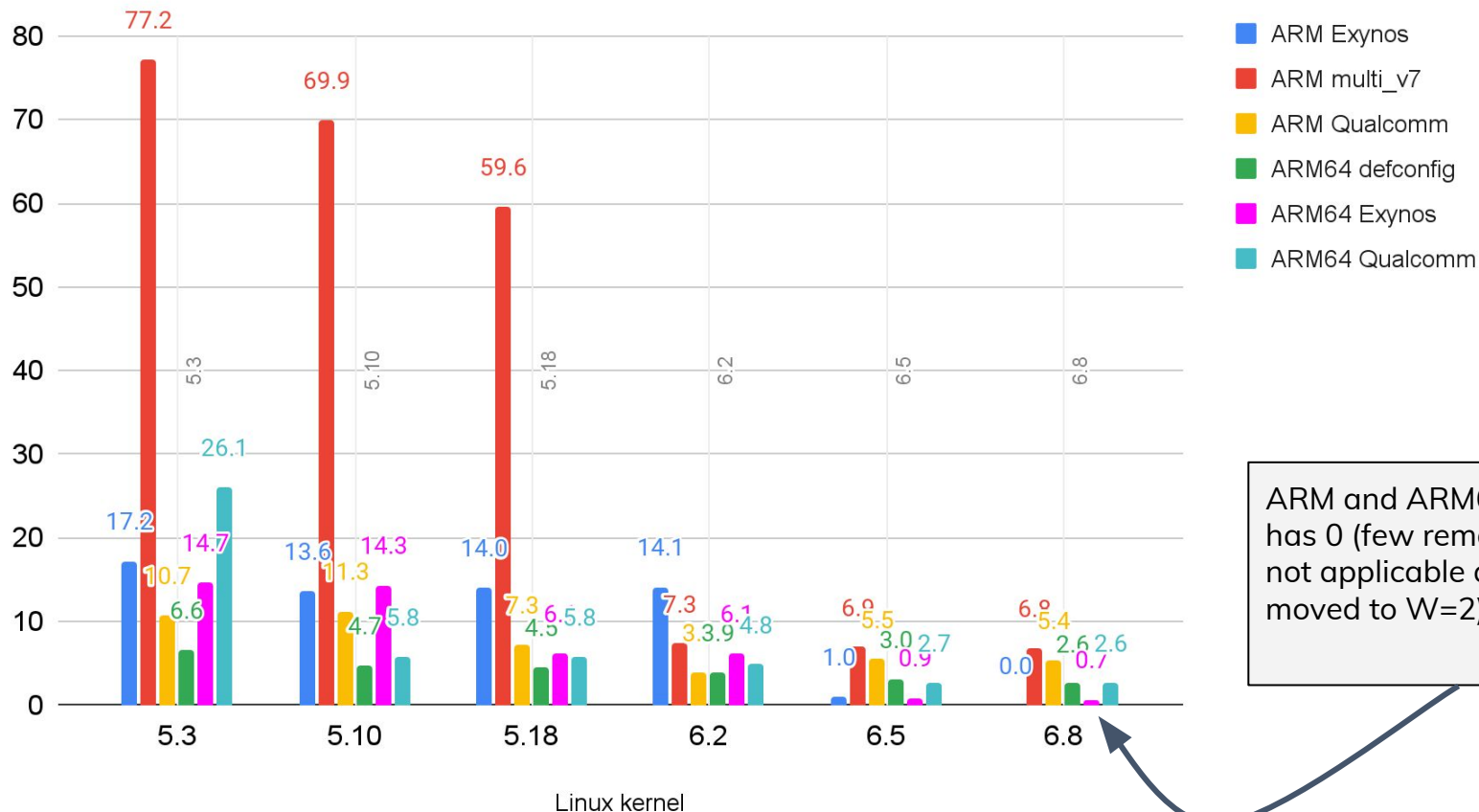
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DT Schema Validation Warnings

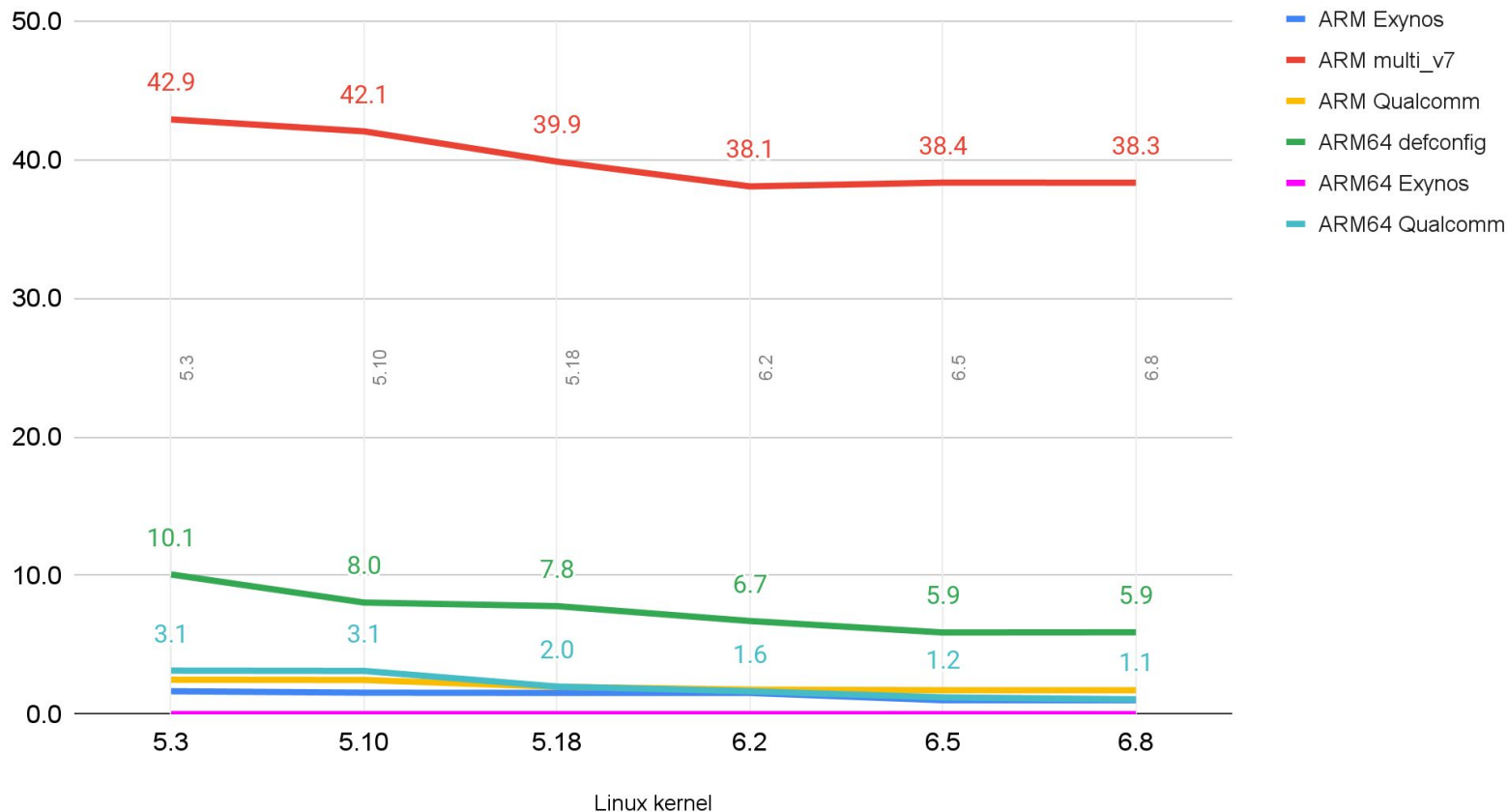
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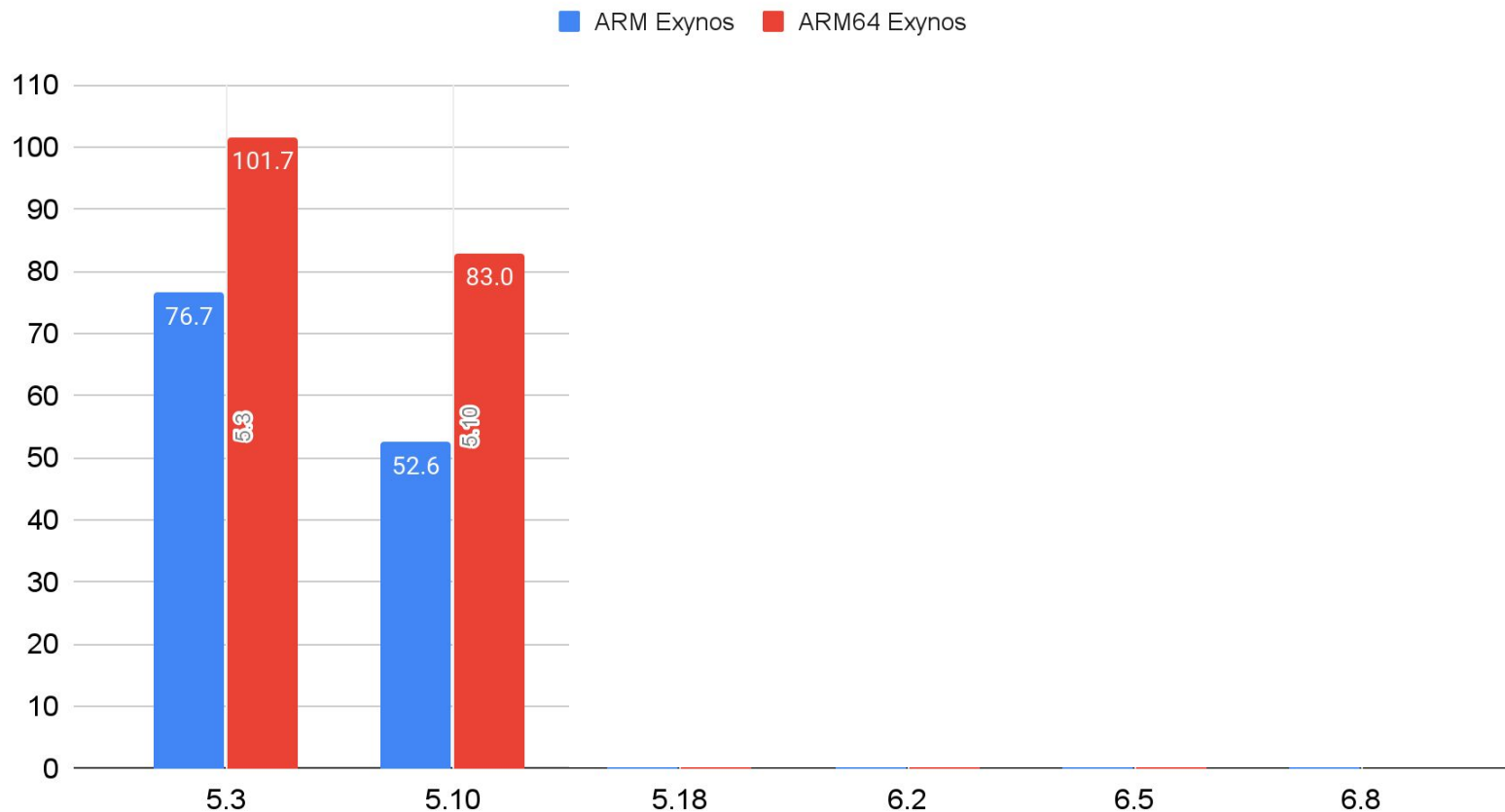
Compatibles not in DT Schema / Target



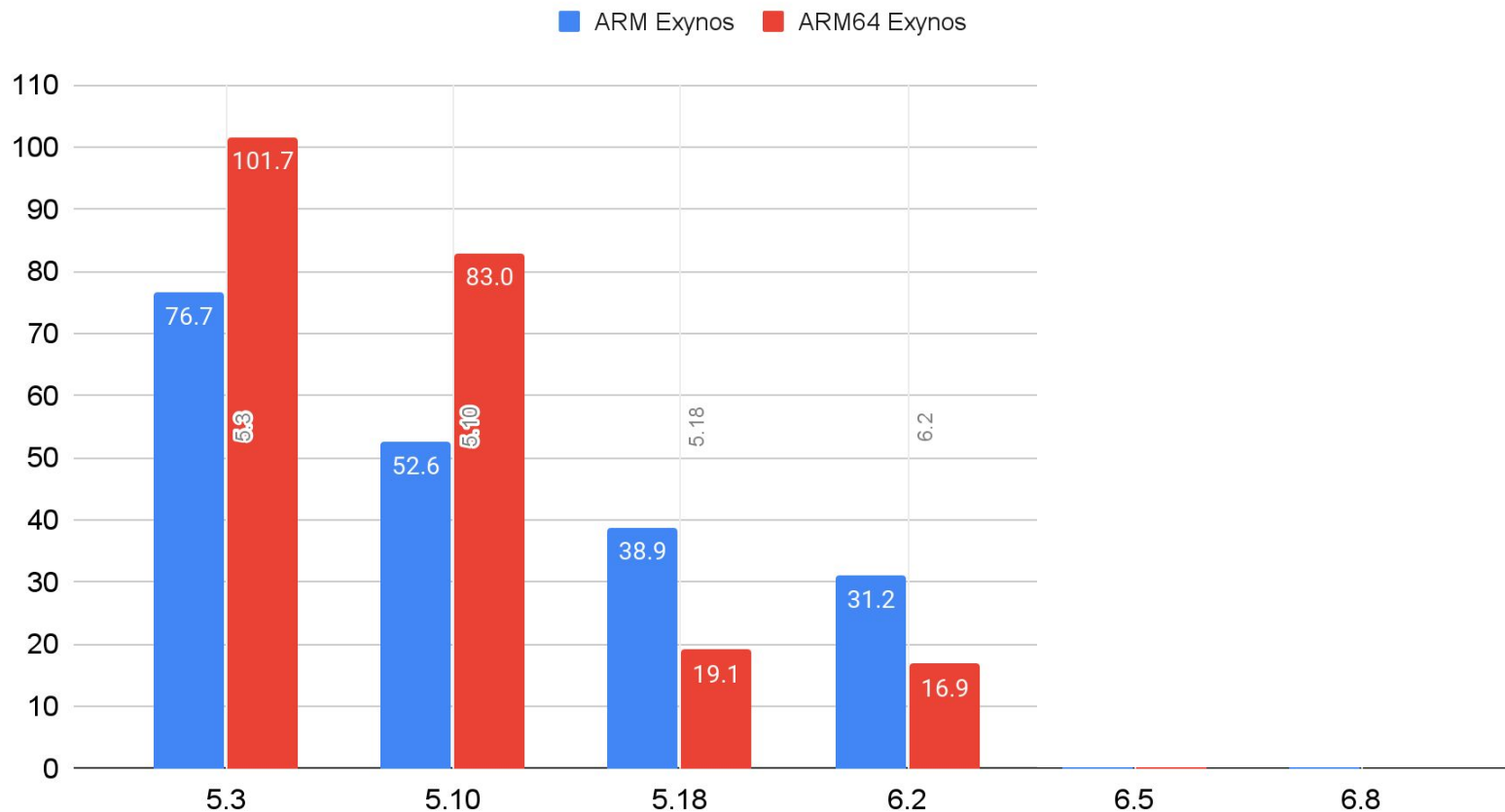
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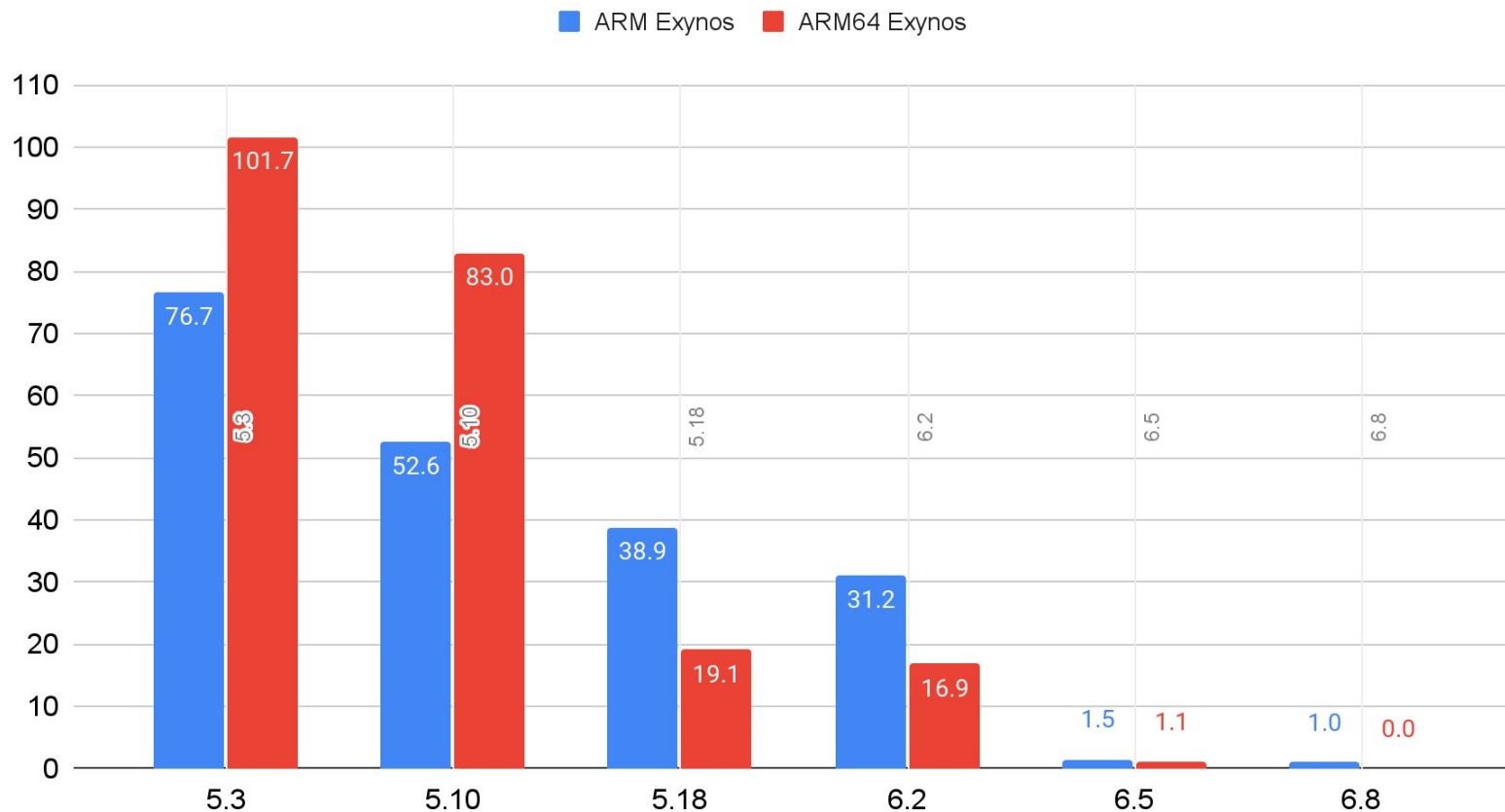
Validation Warnings: Exynos / Target



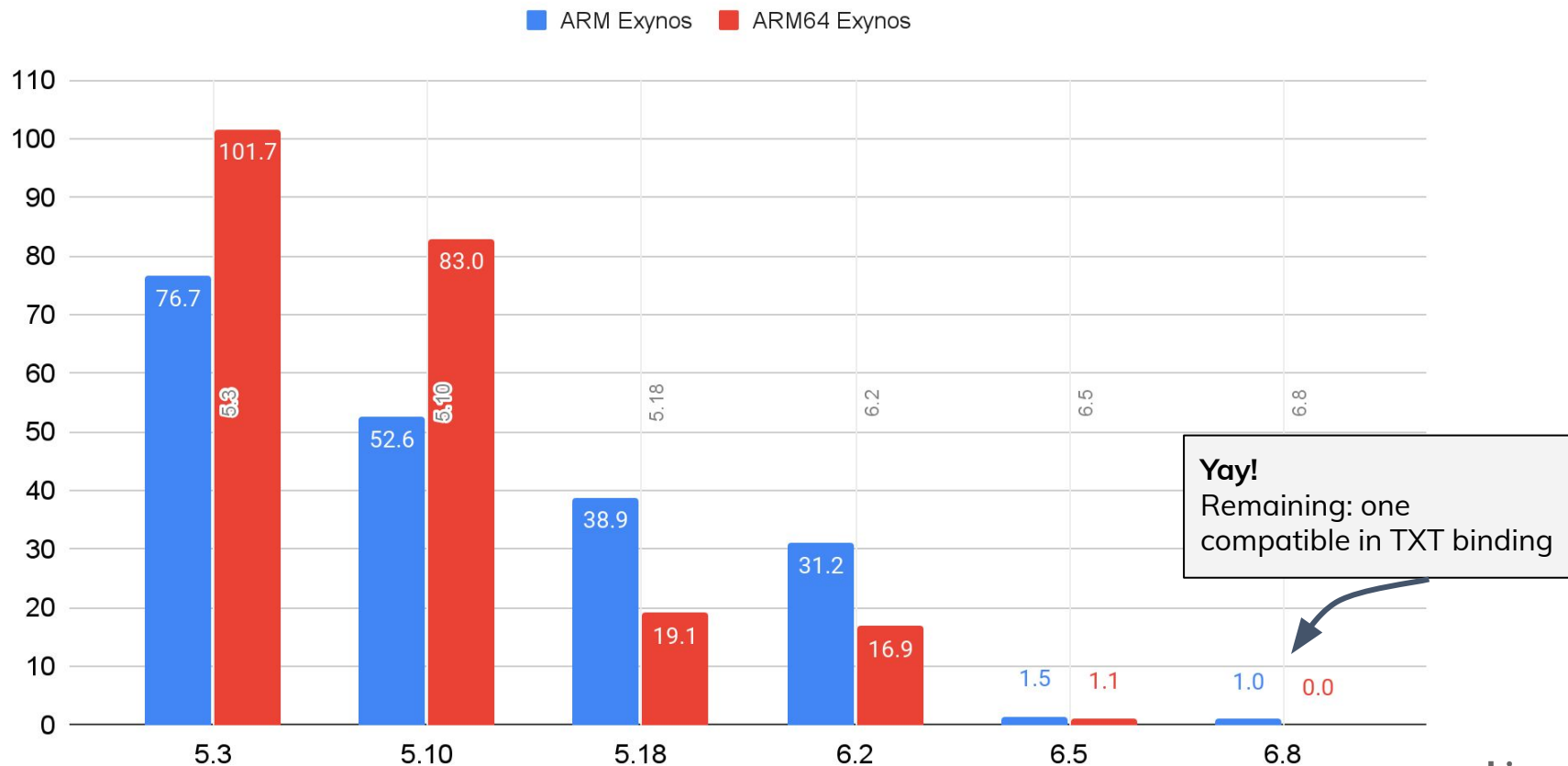
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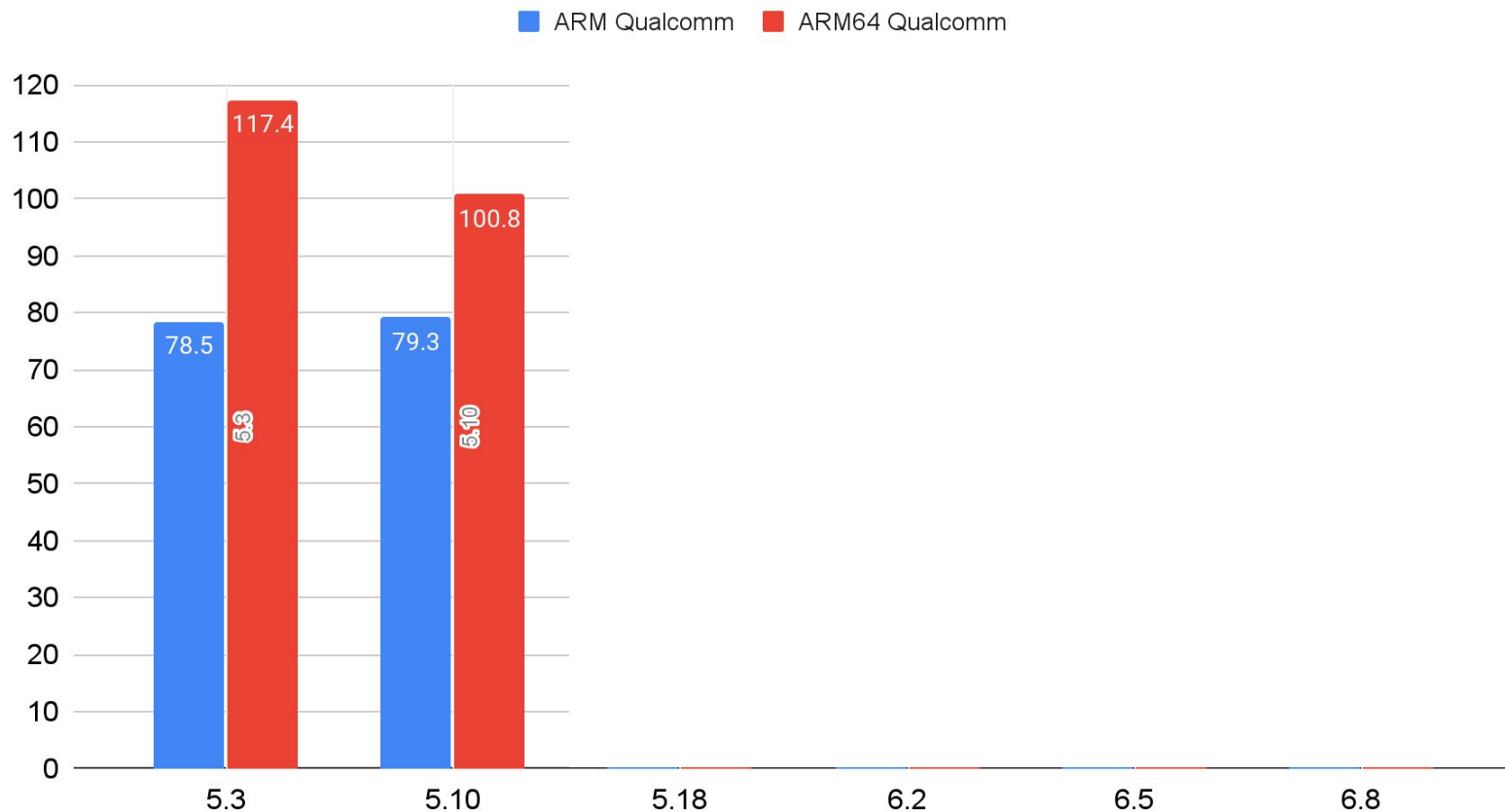
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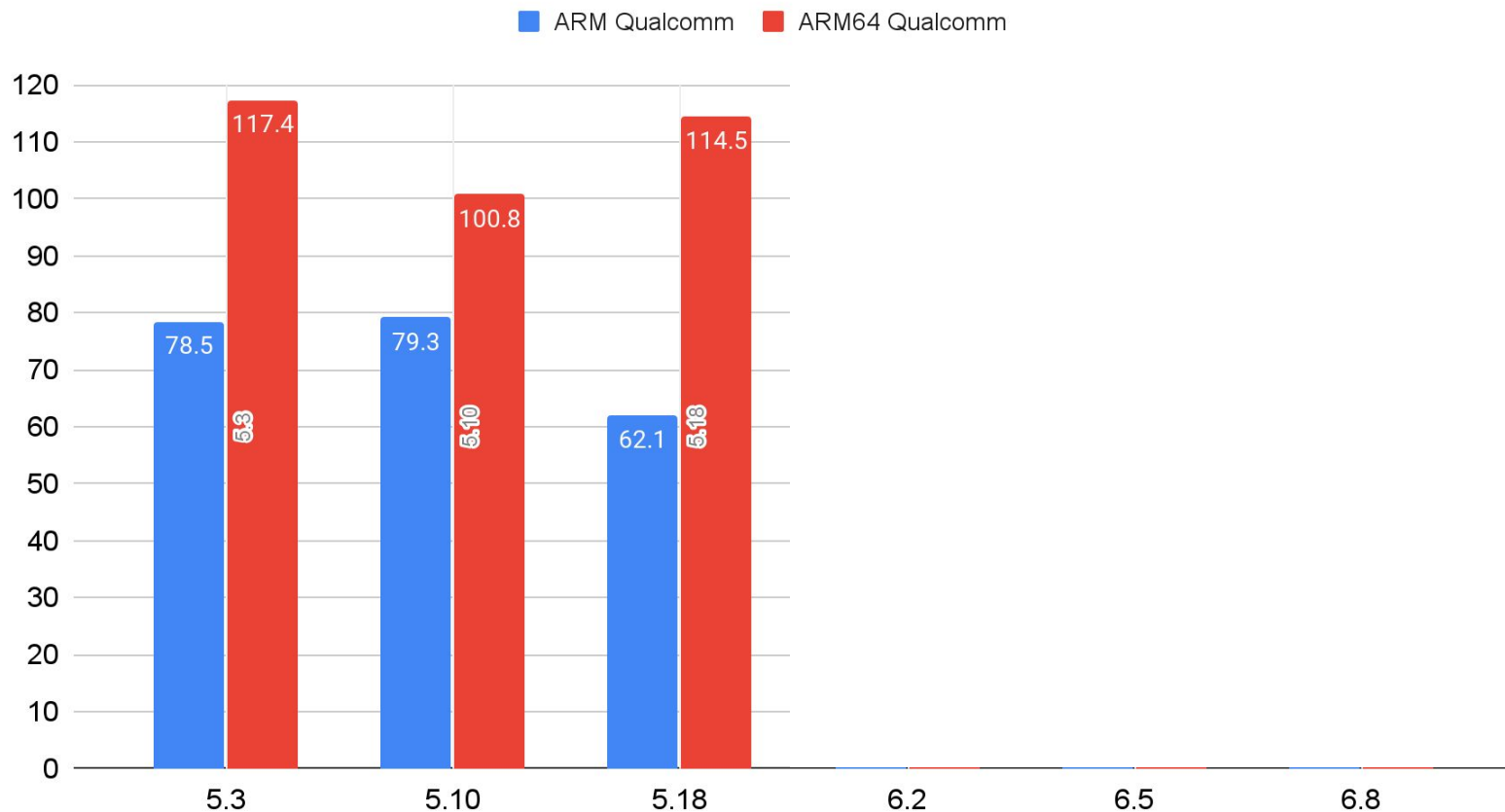
Validation Warnings: Exynos / Target



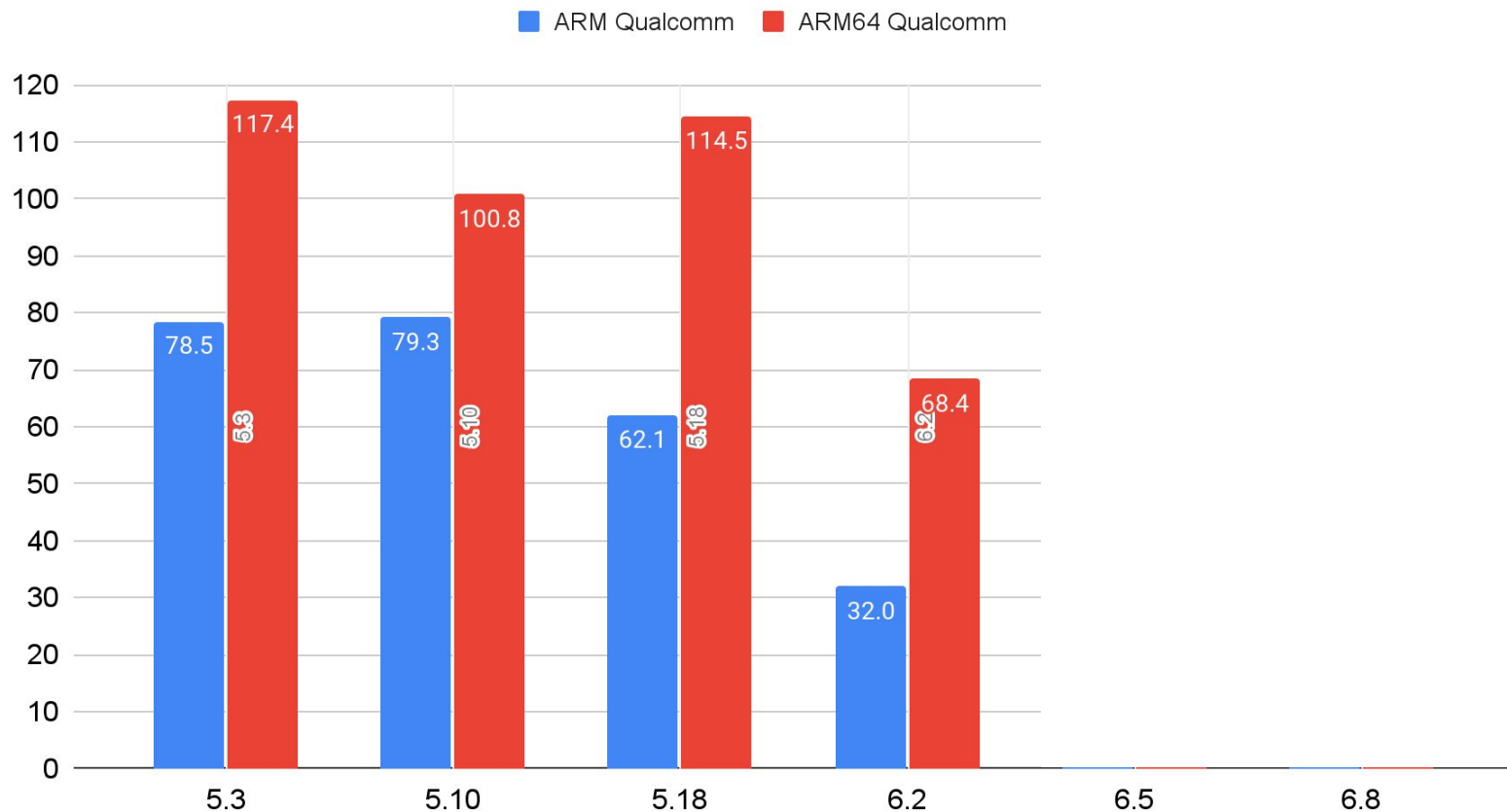
Validation Warnings: Qualcomm / Target



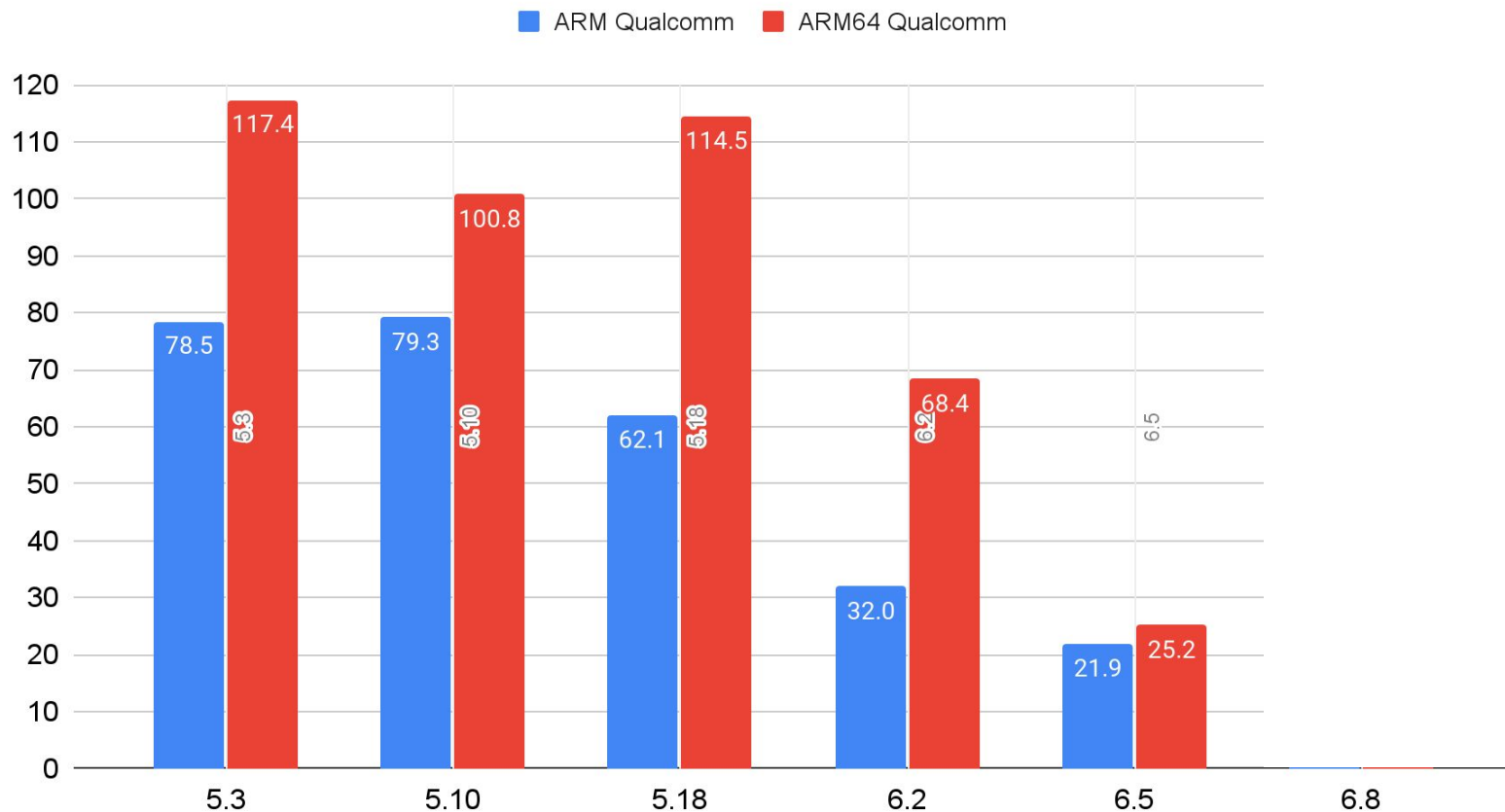
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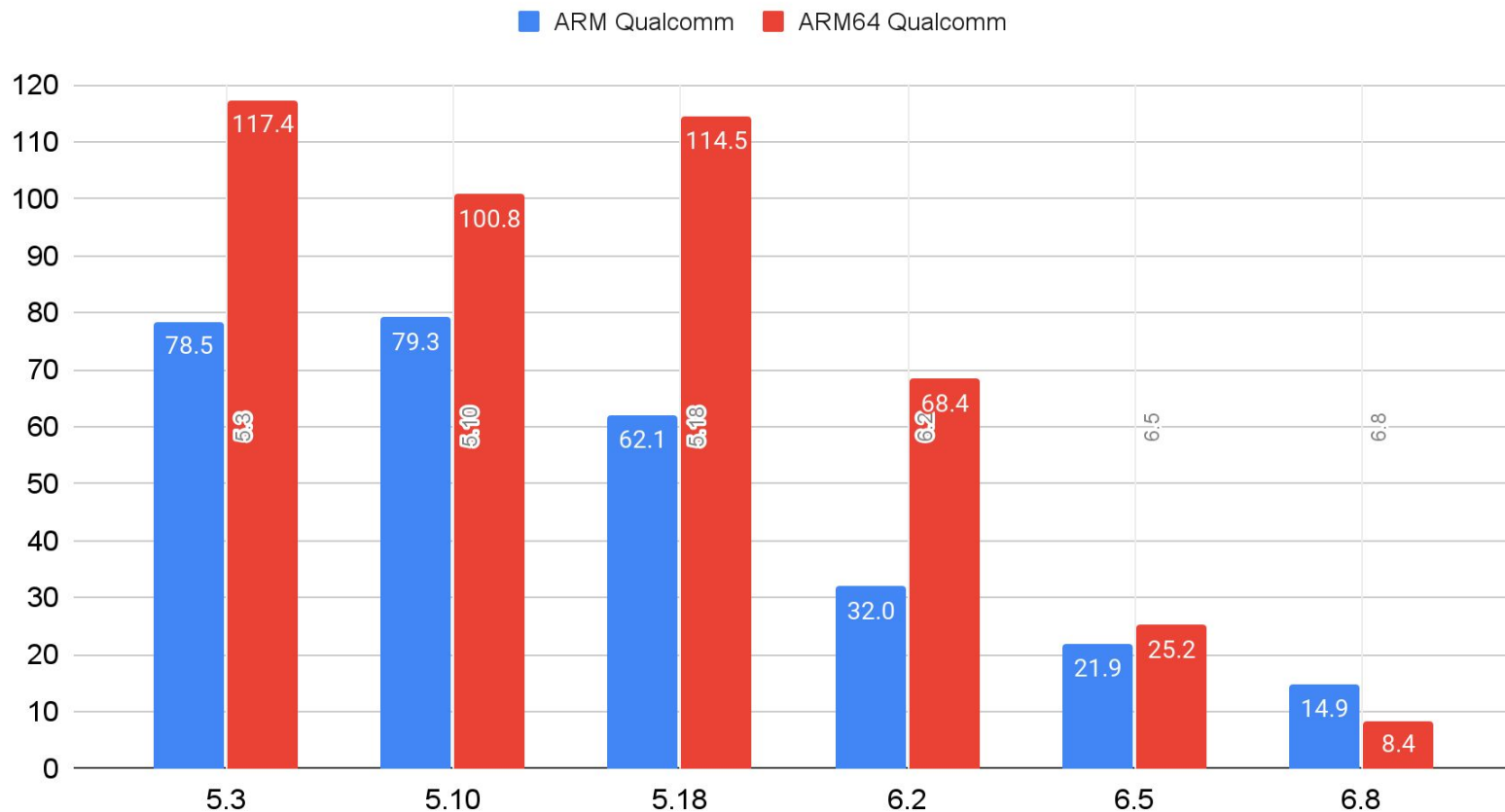
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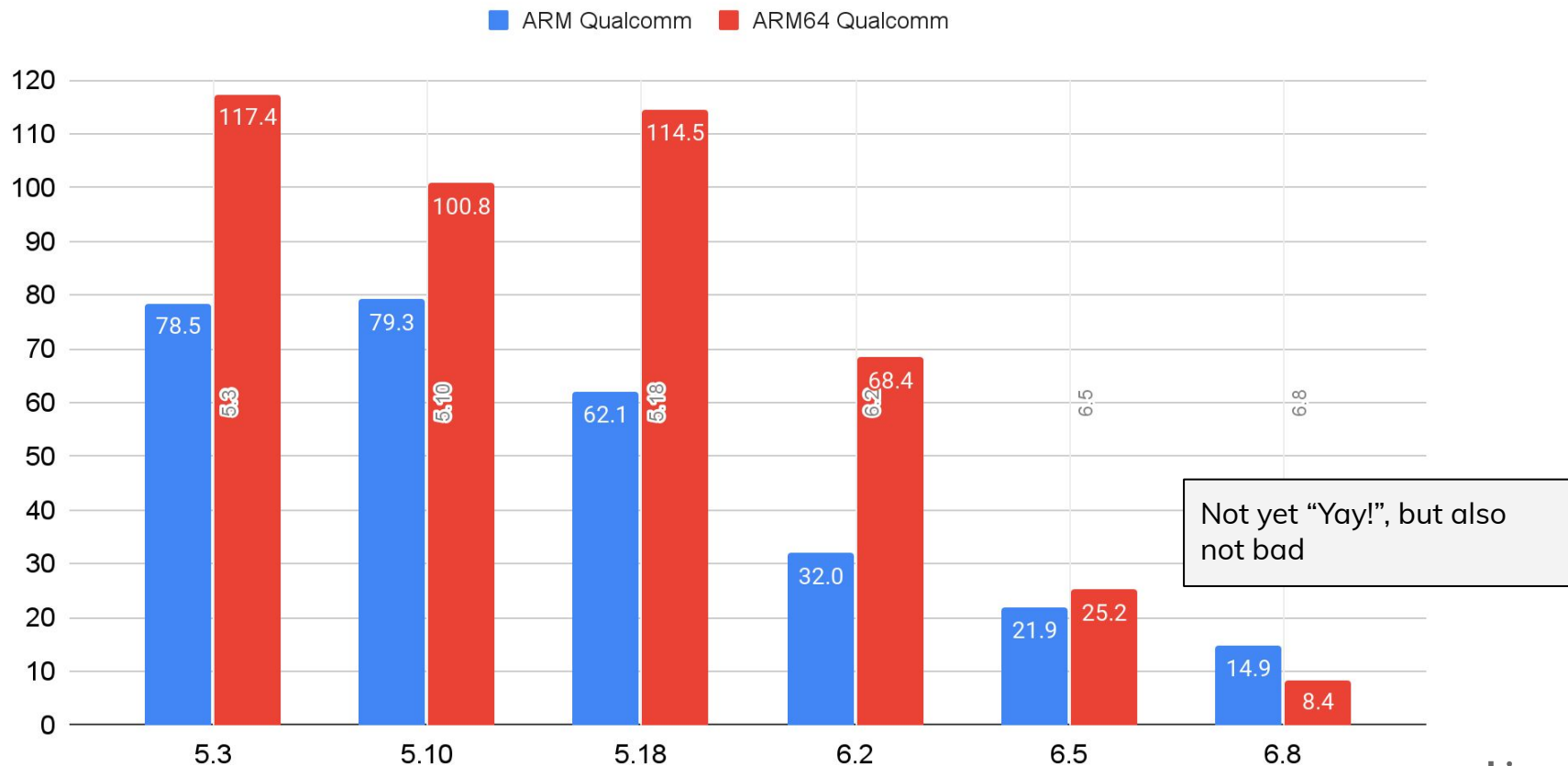
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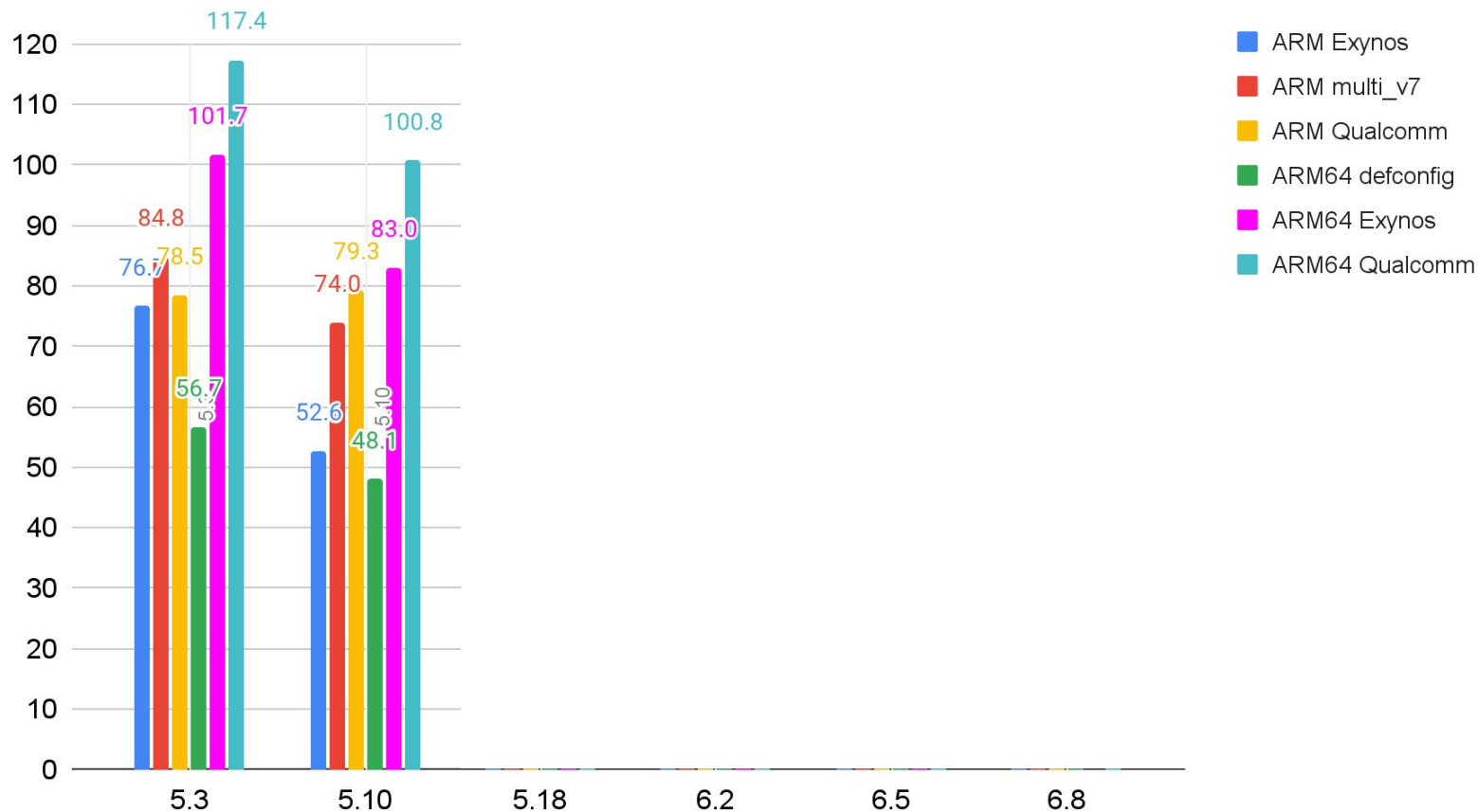
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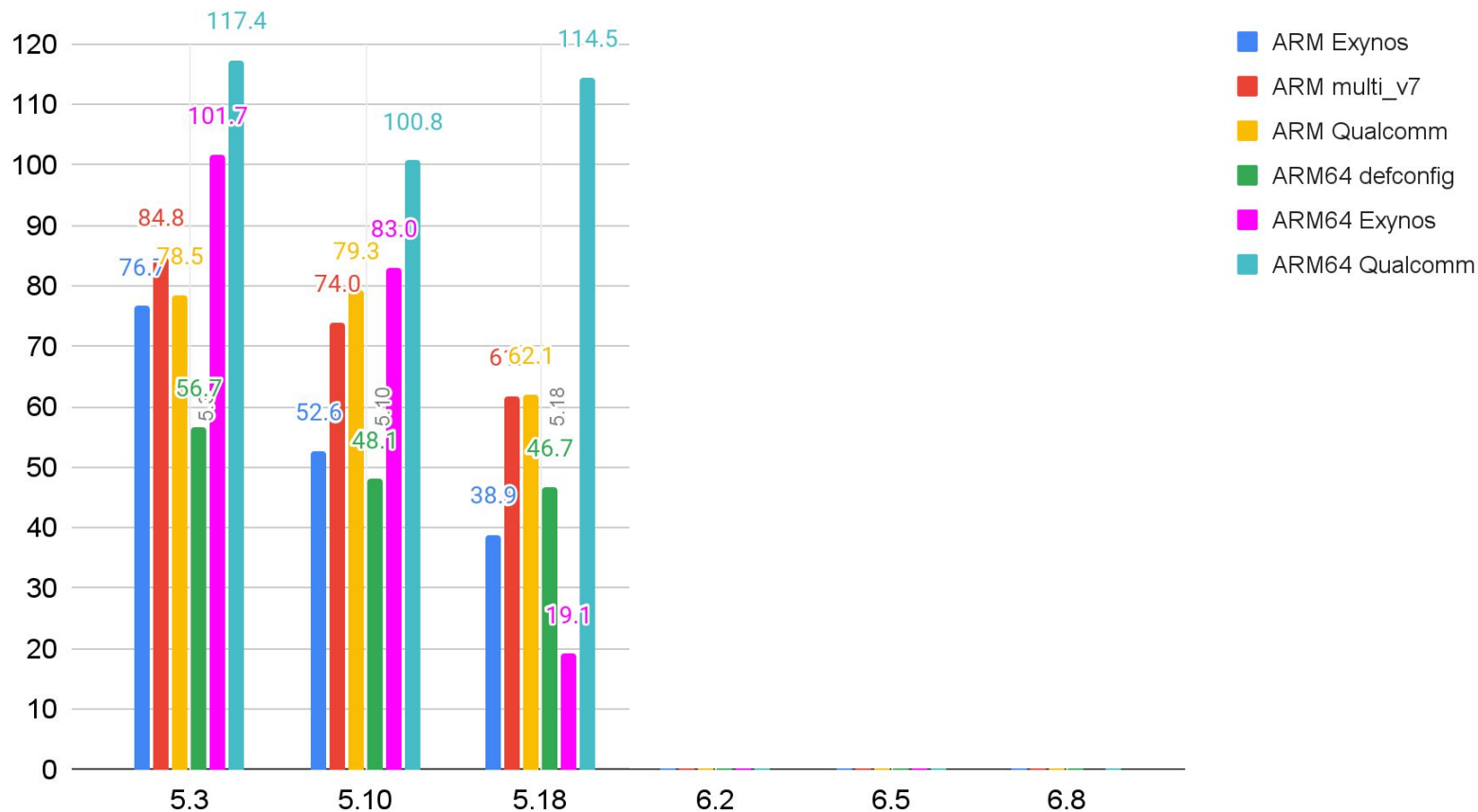
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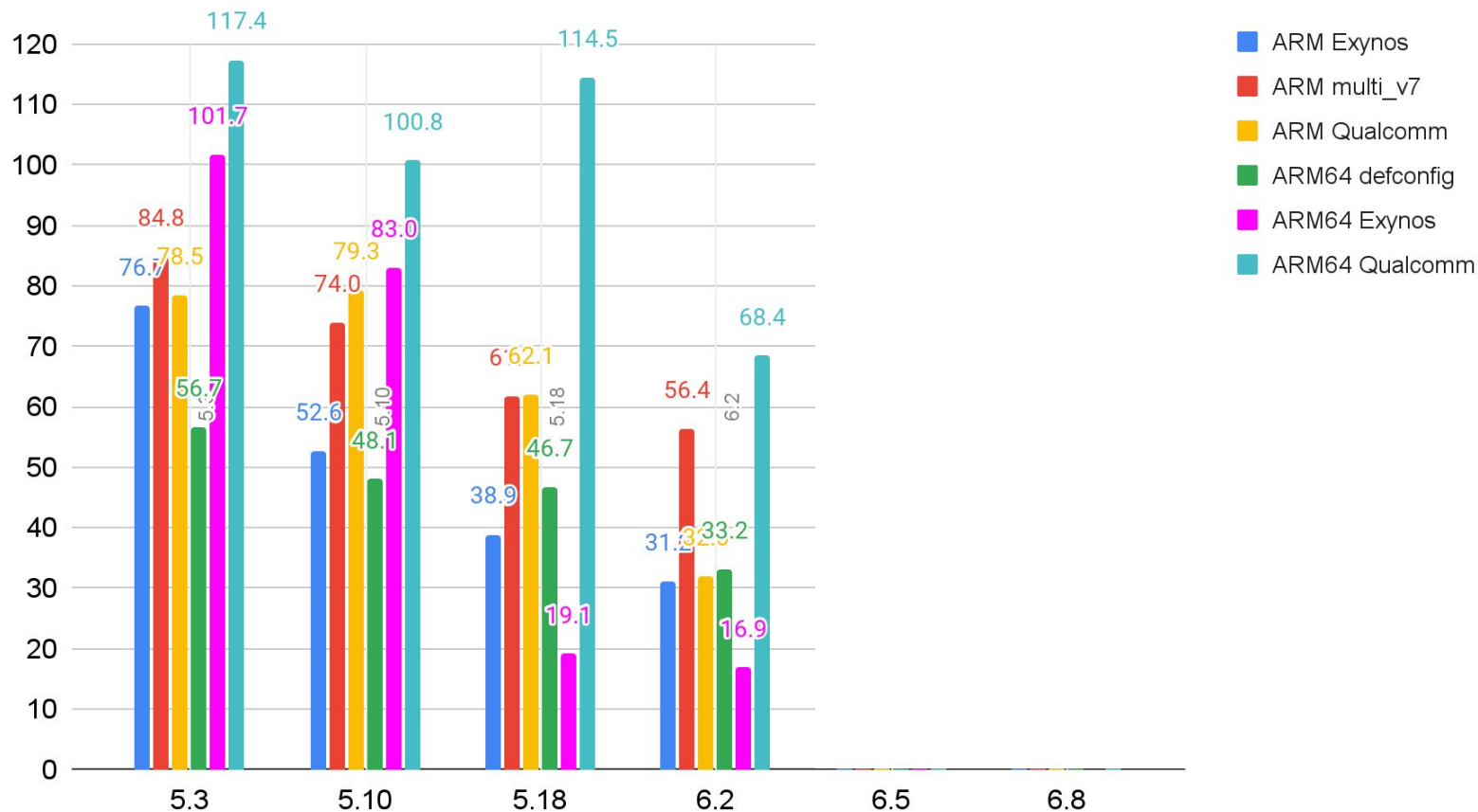
Validation Warnings: All Platforms / Target



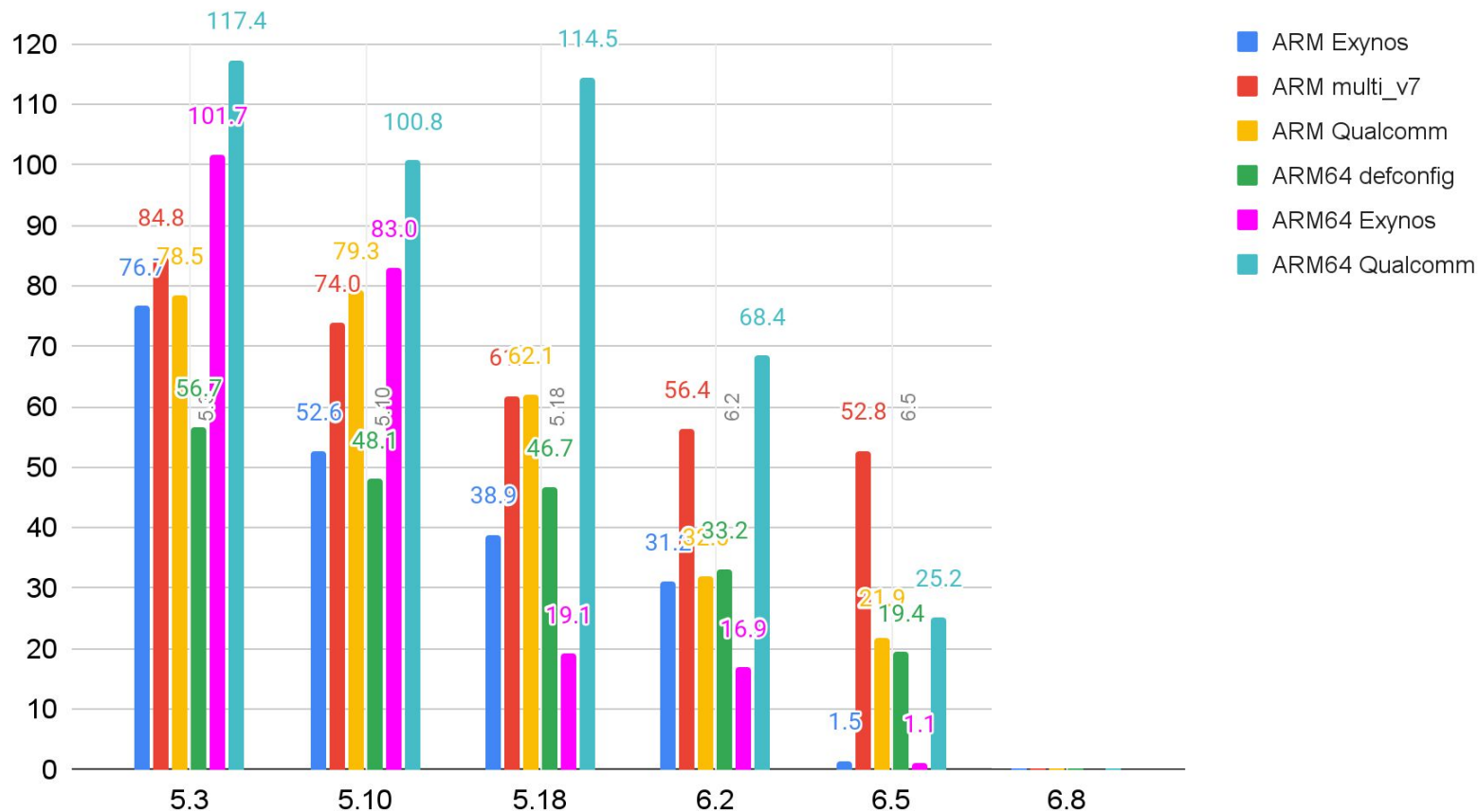
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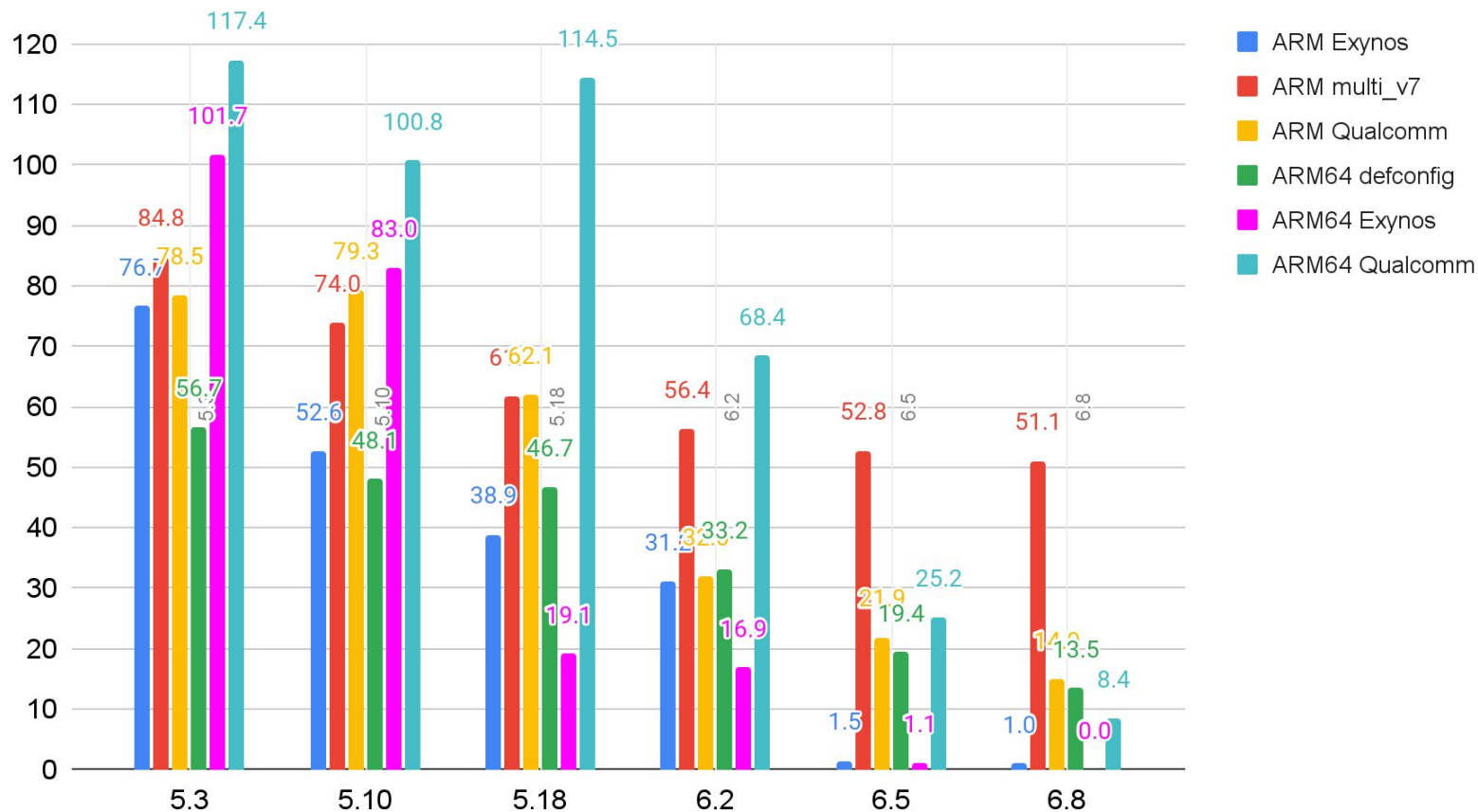
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Why Whac-A-Mole?

DT Schema Validation Warnings / Target

Linux kernel:	v5.3 All / target	v6.8 All / target
arm-exynos	76.7	
arm-qcom	78.5	
arm-multi_v7	84.8	
arm64-exynos		
arm64-qcom		
arm64-defconfig		

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arm64-defconfig	56.7	

DT Schema Validation Warnings / Target

Linux kernel:	v5.3 All / target	v6.8 All / target
arm-exynos	76.7	1.0
arm-qcom	78.5	14.9
arm-multi_v7	84.8	51.1
arm64-exynos	101.7	0.0
arm64-qcom	117.4	8.4
arm64-defconfig	56.7	13.5

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Why Whac-A-Mole?



Sarah Stierch (CC BY 4.0), original: https://commons.wikimedia.org/wiki/File:Circus_Circus_Reno_-_2021-11-14_-_Sarah_Stierch_05.jpg

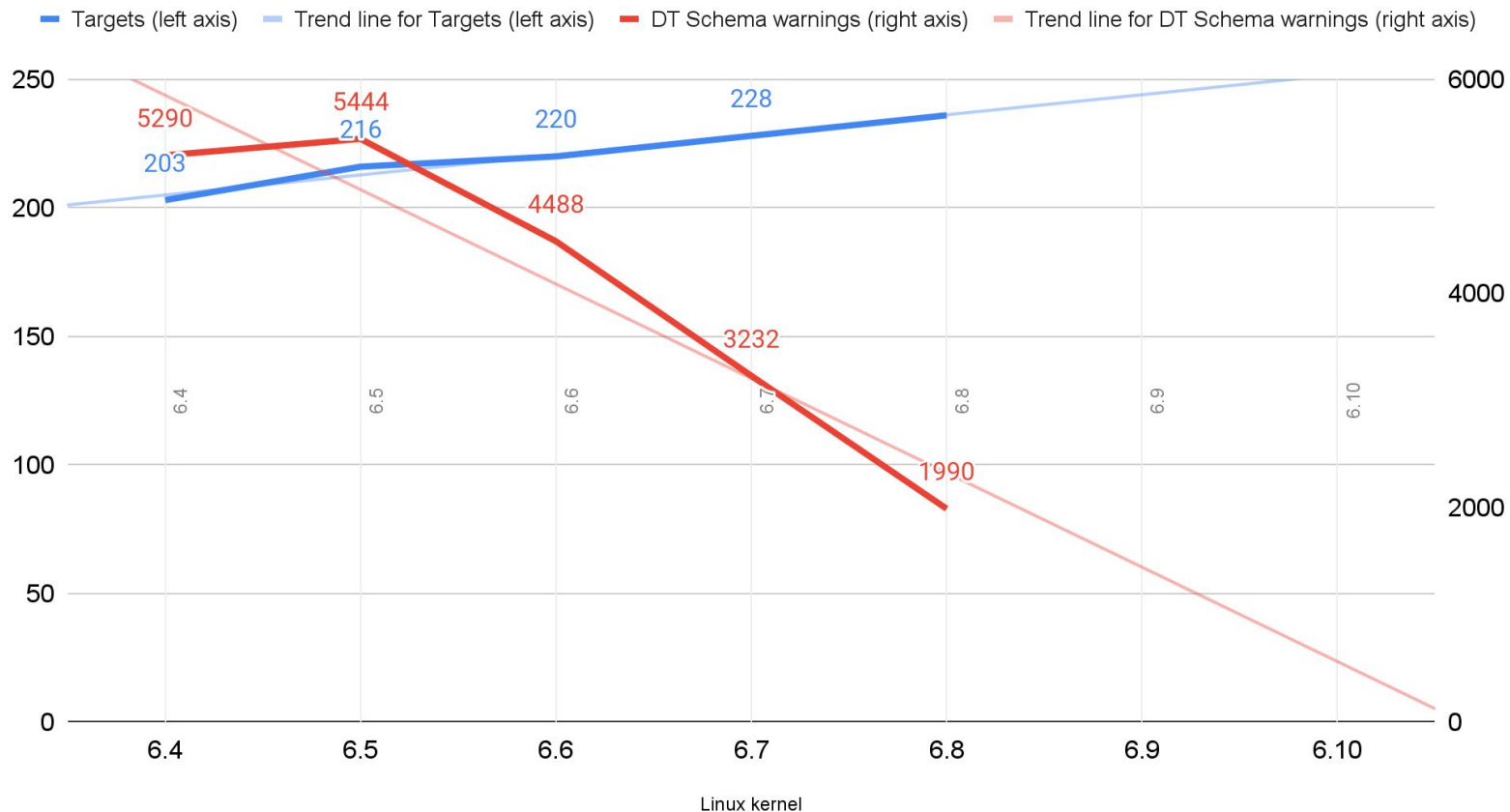
Why Whac-A-Mole?



Moles are amazing creatures. No moles were hurt during DTS validation.

Sarah Stierch (CC BY 4.0), original: https://commons.wikimedia.org/wiki/File:Circus_Circus_Reno_-_2021-11-14_-_Sarah_Stierch_05.jpg

ARM64 Qualcomm: Targets and Warnings



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- Significant effort reduced the total warnings from DT schema validation to much smaller number
 - Some platforms are warnings-free: success!
- But some platforms we cannot get to warnings-free state
 - Newer SoCs within these platforms are usually able to reach warnings-free state:
 - Qualcomm Snapdragon 8 Gen 1 (SM8450), Gen 2 (SM8550) and Gen 3 (SM8650) have just few USB warnings
 - Qualcomm Snapdragon X Elite, once fully merged (around v6.9-rc1), has just few warnings

Was the Effort Worthwhile?

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 - Simple answer: because some tool prints warnings, thus we fix them
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```
exynos3250-rinato.dtb: fimd@11c00000: i80-if-timings: 'wr-act' does not match any of the  
regexes: 'pinctrl-[0-9]+'
```

```
exynos4412-p4note-n8010.dtb: battery-cell: 'power-supplies' does not match any of the regexes:  
'^ocv-capacity-table-[0-9]+$', 'pinctrl-[0-9]+'
```

- These are two similar warnings telling that bindings do not allow given property (*wr-act* and *power-supplies*)

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```

- These are two similar warnings telling that bindings do not allow given property (*wr-act* and *power-supplies*)
 - Such properties should not be there
 - Both warnings could be harmless: redundant property
 - Or maybe there is a mistake in the name and a different needed property is missing?

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Explaining
in commit
msg why you
are doing this?



"This
patch
adds XYZ."

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 - Add baz to fully support drawing donkeys on ACME device
 - Correct addresses of donkey-drawer, to match datasheet
 - Fix warning: “here goes the warning message”

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 - Fix warning: “here goes the warning message”
- Explaining “what” is sometimes also beneficial, especially when it is not obvious

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- Exynos+Qualcomm = ~3500 commits to analyze
- I am not going to look at other SoCs, sorry folks!

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- Because... -ENOTIME

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 - Some parts of warnings...
 - align, nodename...
 - Fixes, CC: stable
 - ... and some more
- ... and then looked at each commit
 - Thank to all Linux kernel contributors who put some sort of valuable information into commit messages:
 - Why did you do it
 - If fixed warning: wrote that you fixed warning

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 - Sometimes committer explained the bigger picture, but not saying issue was found by DT schema
- In other words: I tried to find and then classify all commits which were or could be a result of DT schema warnings
 - Why?
 - Because if commits fix real things, DT schema is good
 - Because if commits fix code style, DT schema is meh

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 - **POSSIBLE FIX**
- Something does not work
 - **REAL FIX**
- Something does not work, but DT schema did not detect it yet
 - **FUTURE FIX**

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 - True especially for trivial style fixes
- Going through Samsung Exynos was a bit easier, because I mentioned warnings in the my commit messages
 - And there was not much other work in the subsystem happening
- Many Qualcomm commits said nothing about warning, nothing about DT schema, but just word “bindings”
 - If only people could answer “why” they are doing what they are doing...

Style

- Coding style, something which is easier to read
- [Just to make DT schema happy](#)

```
qcom,board-id = <8 0>;
clocks {
-     compatible = "simple-bus";
-
    div1_mclk: divclk1 {
        compatible = "gpio-gate-clock";
        pinctrl-0 = <&audio_mclk_pin>;
```

Style

- Coding style, something which is easier to read
- [Just to make DT schema happy](#)
- [Conforming to Devicetree specification requirements about node names](#)
 - Node names should be generic, e.g. `flash`, not `m25p80`

```
cs-select = <0>;
status = "okay";
- m25p80@0 {
+ flash@0 {
    #address-cells = <1>;
    #size-cells = <1>;
    reg = <0>;
```

Style

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- [Conforming to Devicetree specification requirements about node names](#)
 - Node names should be generic, e.g. i2c, not pca9541
- [Redundant properties, except cases when they could affect drivers](#)

```
broken-cd;  
non-removable;  
cap-mmc-highspeed;  
- desc-num = <4>;  
mmc-hs200-1_8v;  
card-detect-delay = <200>;  
vmmc-supply = <&vemmc_reg>;
```

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- Coding style, something which is easier to read
- [Just to make DT schema happy](#)
- [Conforming to Devicetree specification requirements about node names](#)
 - Node names should be generic, e.g. i2c, not pca9541
- [Redundant properties, except cases when they could affect drivers](#)
- Code was working correct, always

Improvement

- Code quality improvement, [beyond pure style](#)

```
};  
  
&mct {  
-    compatible = "none";  
+    status = "disabled";  
};  
  
&mdma1 {
```

Improvement

- Code quality improvement, [beyond pure style](#)
- [Includes switching away from deprecated properties, like gpio->gpios](#)

```
CPVDD-supply = <&vbatt_reg>;
SPKVDD1-supply = <&vbatt_reg>;
SPKVDD2-supply = <&vbatt_reg>;
- wlf,l道1ena = <&gpj0 4 GPIO_ACTIVE_HIGH>;
- wlf,l道2ena = <&gpj0 4 GPIO_ACTIVE_HIGH>;
+ wlf,l道1ena-gpios = <&gpj0 4 GPIO_ACTIVE_HIGH>;
+ wlf,l道2ena-gpios = <&gpj0 4 GPIO_ACTIVE_HIGH>;
};
};
```


Improvement

- Code quality improvement, [beyond pure style](#)
- [Includes switching away from deprecated properties, like gpio->gpios](#)
- [Proper hardware description in DTS, without impact on Linux, but making it correct](#)

```
@@ -3418,12 +3418,12 @@ timer@17800000 {
    reg = <0 0x17800000 0 0x1000>;
    #address-cells = <2>;
-    #size-cells = <2>;
-    ranges;
+    #size-cells = <1>;
+    ranges = <0 0 0 0 0x20000000>;
    frame@17801000 {
-        reg = <0 0x17801000 0 0x1000>,
-            <0 0x17802000 0 0x1000>;
+        reg = <0 0x17801000 0x1000>,
+            <0 0x17802000 0x1000>;
        interrupts = <GIC_SPI 8 IRQ_TYPE_LEVEL_HIGH>,
                    <GIC_SPI 6 IRQ_TYPE_LEVEL_HIGH>;
```

Improvement

- Code quality improvement, [beyond pure style](#)
- [Includes switching away from deprecated properties, like gpio->gpios](#)
- [Proper hardware description in DTS, without impact on Linux, but making it correct](#)
- [Missing compatibles, e.g. for syscon or for cases where bindings ask for compatibles](#)

```
};  
  
gpi_dma2: dma-controller@8000000 {  
-     compatible = "qcom,sm8450-gpi-dma";  
+     compatible = "qcom,sm8450-gpi-dma", "qcom,sm6350-gpi-dma";  
    #dma-cells = <3>;  
    reg = <0 0x8000000 0 0x60000>;  
    interrupts = <GIC_SPI 588 IRQ_TYPE_LEVEL_HIGH>,  
    
```

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- [Includes switching away from deprecated properties, like gpio->gpios](#)
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- [Redundant properties, if they could affect drivers](#)

```
qcom,ports-word-length = /bits/ 8 <0xFF 0xFF 0xFF 0xFF 0xFF>;  
qcom,ports-block-group-count = /bits/ 8 <0xFF 0xFF 0xFF 0xFF 0xFF>;  
qcom,ports-lane-control = /bits/ 8 <0xFF 0x00 0x01 0x00 0x01>;  
- qcom,port-offset = <1>;  
  #sound-dai-cells = <1>;  
  #address-cells = <2>;  
  #size-cells = <0>;
```

Improvement

- Code quality improvement, beyond pure style
- Includes switching away from deprecated properties, like gpio->gpios
- Proper hardware description in DTS, without impact on Linux, but making it correct
- Missing compatibles, e.g. for syscon or for cases where bindings ask for compatibles
- Redundant properties, if they could affect drivers
- Original code was working correct, at least on Linux side

Possible Fix

- DTS is not correct or complete, but no impact was observed or at least reported

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- DTS is not correct or complete, but no impact was observed or at least reported
- Missing properties which can affect some drivers
 - [Missing regulator supplies, because future kernel can turn them off without if there is no consumer](#)

```
        status = "okay";
    };
+&usbdrd {
+    vdd10-supply = <&ldo4_reg>;
+    vdd33-supply = <&ldo6_reg>;
+};
+
&usbdrd_phy {
    vbus-supply = <&usb30_vbus_reg>;
    vbus-boost-supply = <&usb3drd_boost_5v>;
```

Possible Fix

- DTS is not correct or complete, but no impact was observed or at least reported
- Missing properties which can affect some drivers
 - [Missing regulator supplies, because future kernel can turn them off without if there is no consumer](#)
- [Incorrect properties, which seems without impact](#)

```
max98504: amplifier@31 {  
    compatible = "maxim,max98504";  
    reg = <0x31>;  
-    maxim,rx-path = <1>;  
-    maxim,tx-path = <1>;  
-    maxim,tx-channel-mask = <3>;  
-    maxim,tx-channel-source = <2>;  
+  
+    DIOVDD-supply = <&ldo3_reg>;  
+    DVDD-supply = <&ldo3_reg>;  
+    /* PVDD-supply to VPH_PWR */  
};  
};
```

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 - [Missing regulator supplies, because future kernel can turn them off without if there is no consumer](#)
- [Incorrect properties, which seems without impact](#)
- [Different entries in xxx-names \(e.g. clock-names\), which might not affect Linux but other users](#)
 - Includes different order of such entries, because we expect entries to be almost always strictly ordered

```
clocks = <&gcc GCC_CFG_NOC_USB3_PRIM_AXI_CLK>,  
         <&gcc GCC_USB30_PRIM_MASTER_CLK>,  
         <&gcc GCC_AGGRE_USB3_PRIM_AXI_CLK>,  
-        <&gcc GCC_USB30_PRIM MOCK_UTMI_CLK>,  
         <&gcc GCC_USB30_PRIM_SLEEP_CLK>,  
+        <&gcc GCC_USB30_PRIM MOCK_UTMI_CLK>,
```


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- Even if original code was working correct, other projects like U-Boot could be affected

Real Fix

- Real or known impact on users

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```
-      function = LED_FUNCTION_INDICATOR;  
      color = <LED_COLOR_ID_GREEN>;  
      gpios = <&pm8150_gpios 10 GPIO_ACTIVE_HIGH>;  
+      linux,default-trigger = "panic-indicator";  
      default-state = "off";  
+      panic-indicator;  
};  
led-wlan {
```

Real Fix

- Real or known impact on users
- Sometimes impact not tested, but to all means should be
- Incorrect properties with impact

```
pm2250_s3: s3 {  
    /* 0.4V-1.6625V -> 1.3V (Power tree requirements) */  
-    regulator-min-microvolts = <1350000>;  
-    regulator-max-microvolts = <1350000>;  
+    regulator-min-microvolt = <1352000>;  
+    regulator-max-microvolt = <1352000>;  
    regulator-boot-on;  
};
```

Real Fix

- Real or known impact on users
- Sometimes impact not tested, but to all means should be
- Incorrect properties with impact
- Linux driver still might work, but only in certain conditions (e.g. clk_ignore_unused) or on specific Linux version

```
pinctrl-0 = <&ufs_rst_n &ufs_refclk_out>;  
phys = <&ufs_0_phy>;  
phy-names = "ufs-phy";  
- samsung,sysreg = <&syscon_fsys2>;  
- samsung,ufs-shareability-reg-offset = <0x710>;  
+ samsung,sysreg = <&syscon_fsys2 0x710>;  
status = "disabled";  
  
};  
  
};
```

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- [Sometimes impact not tested, but to all means should be](#)
- [Incorrect properties with impact](#)
- [Linux driver still might work, but only in certain conditions \(e.g. clk_ignore_unused\) or on specific Linux version](#)
- [Incorrect name for supplies](#), considered usually a real fix, because if someone bothered to add supply, means this is real supply on schematics

```
hpd-gpios = <&gpx3 7 GPIO_ACTIVE_HIGH>;
pinctrl-names = "default";
pinctrl-0 = <&hdmi_hpd_irq>;
+ vdd-supply = <&ldo6_reg>;
+ vdd_osc-supply = <&ldo7_reg>;
+ vdd_pll-supply = <&ldo6_reg>;
};
```

Future Fix

- I found also one case which was a real issue, so something did not work and users were affected, however DT schema did not report it as DTS warning
- [But future DT schema could report it \(wait for it!\)](#)

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```
thermal-zones {
    cpu0_thermal: cpu0-thermal {
-       thermal-sensors = <&tmu_cpu0 0>;
+       thermal-sensors = <&tmu_cpu0>;
        trips {
            cpu0_alert0: cpu-alert-0 {
                temperature = <70000>; /* millicelsius */
            }
        }
    }
}
```




Results! Tadaa!

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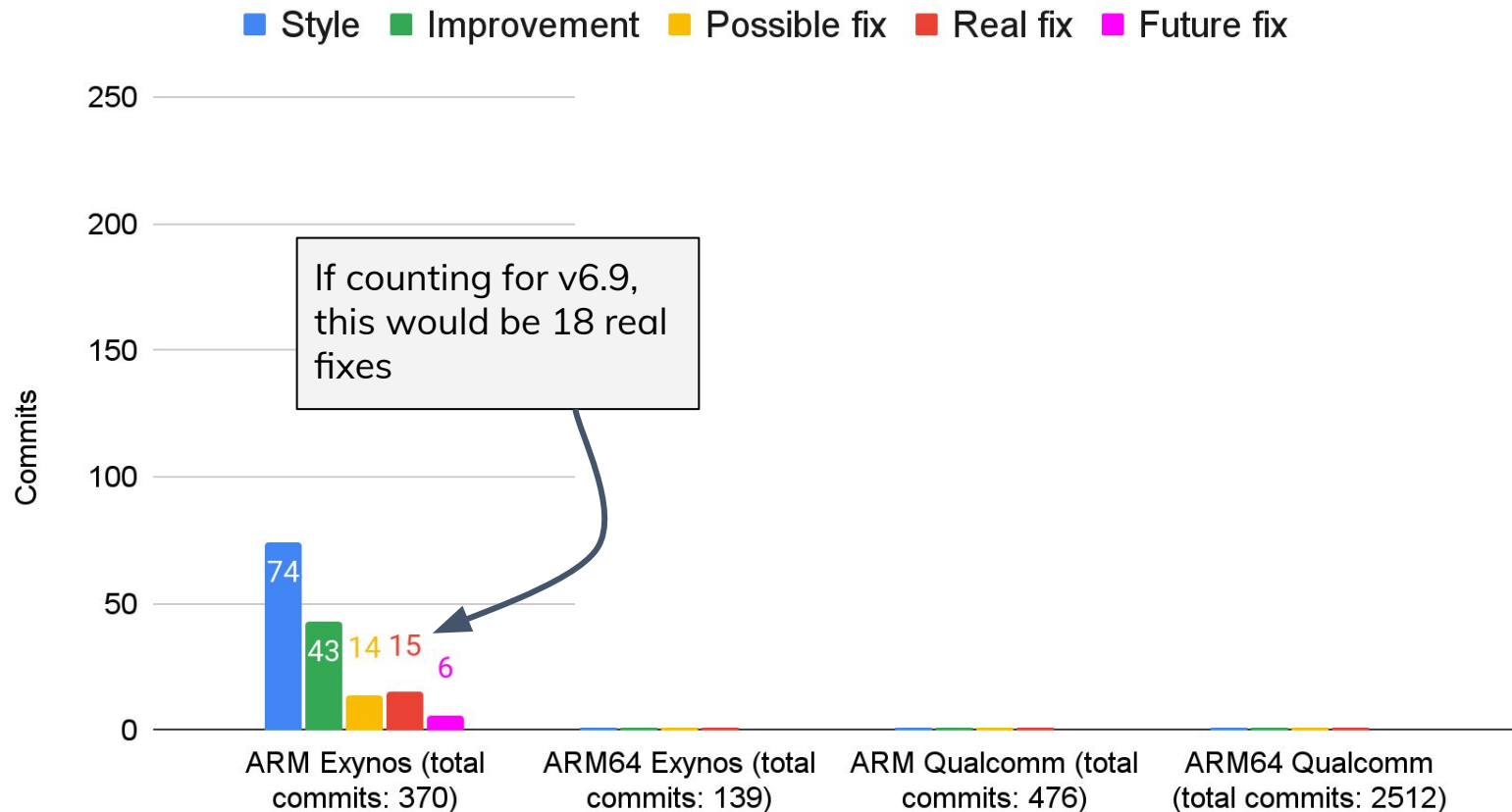
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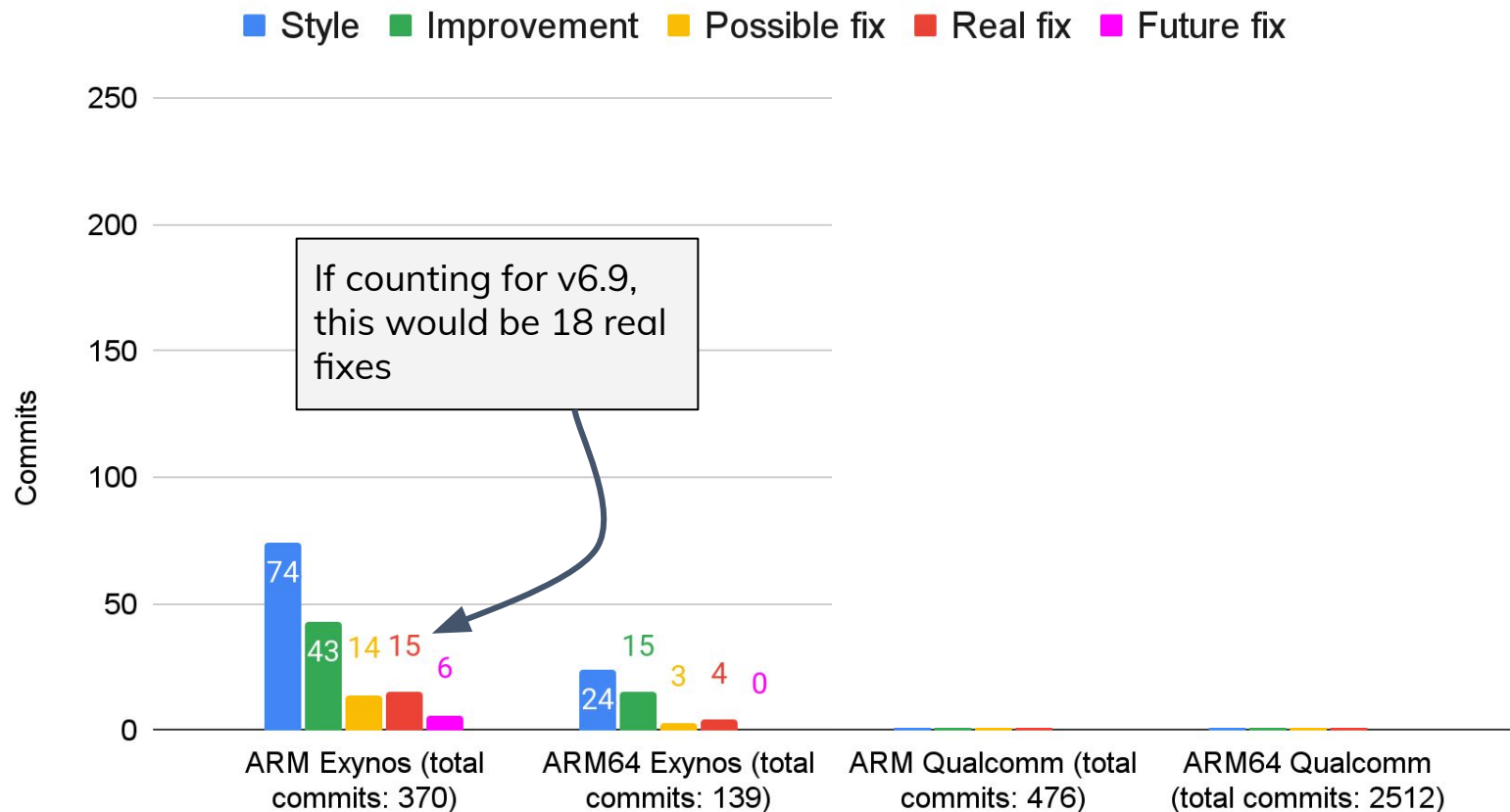
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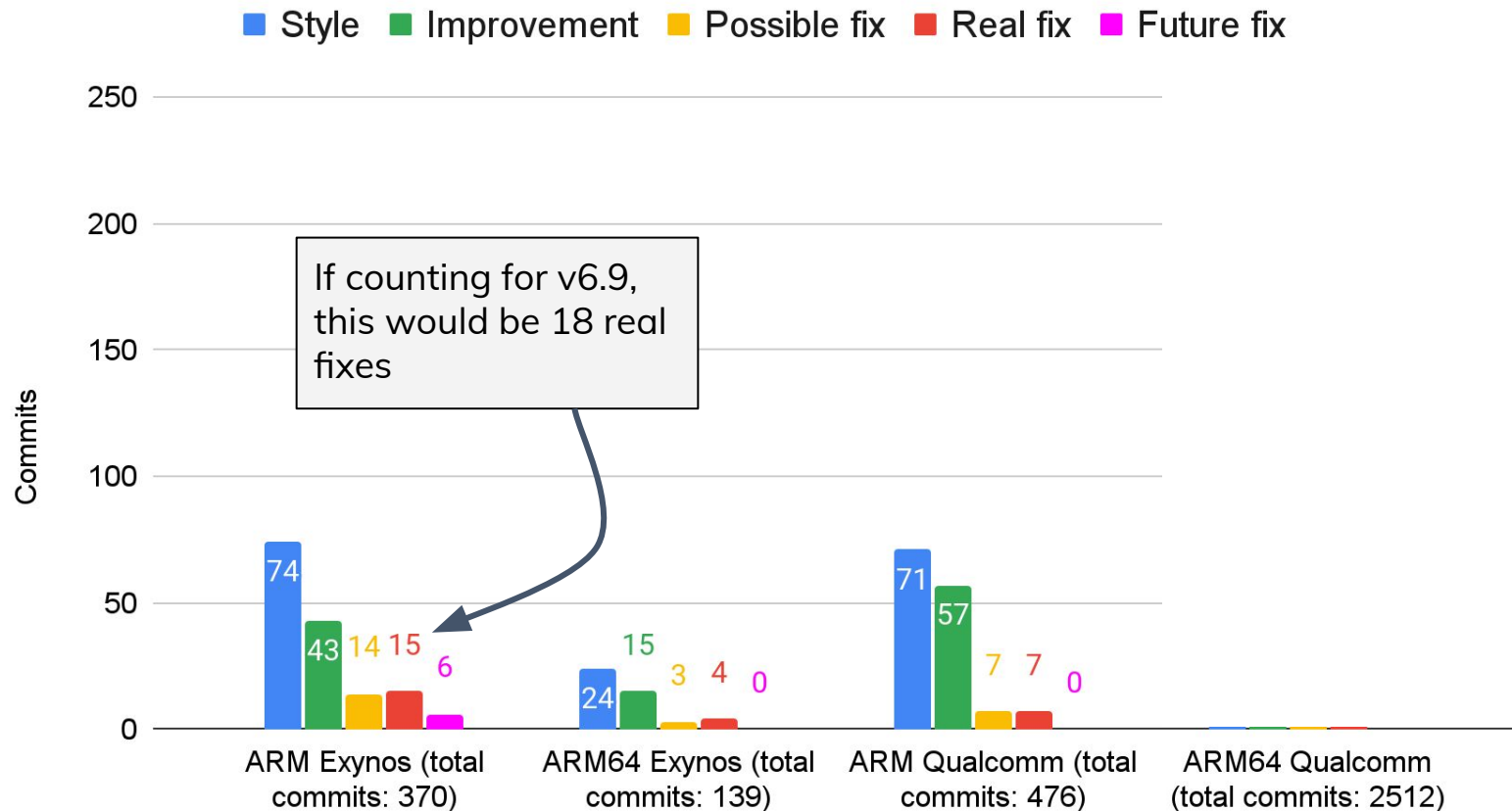
Commits as a Result of Validation



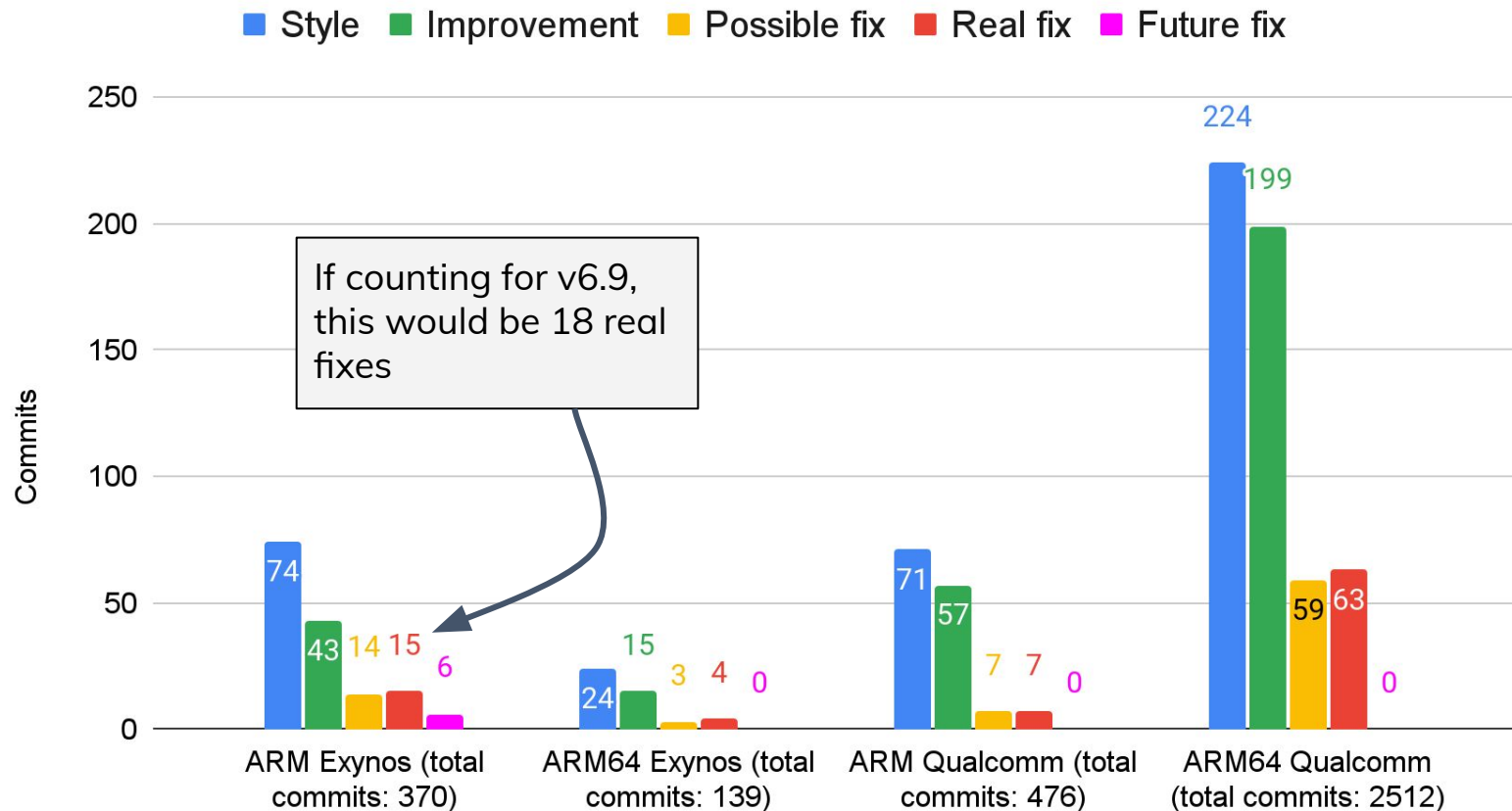
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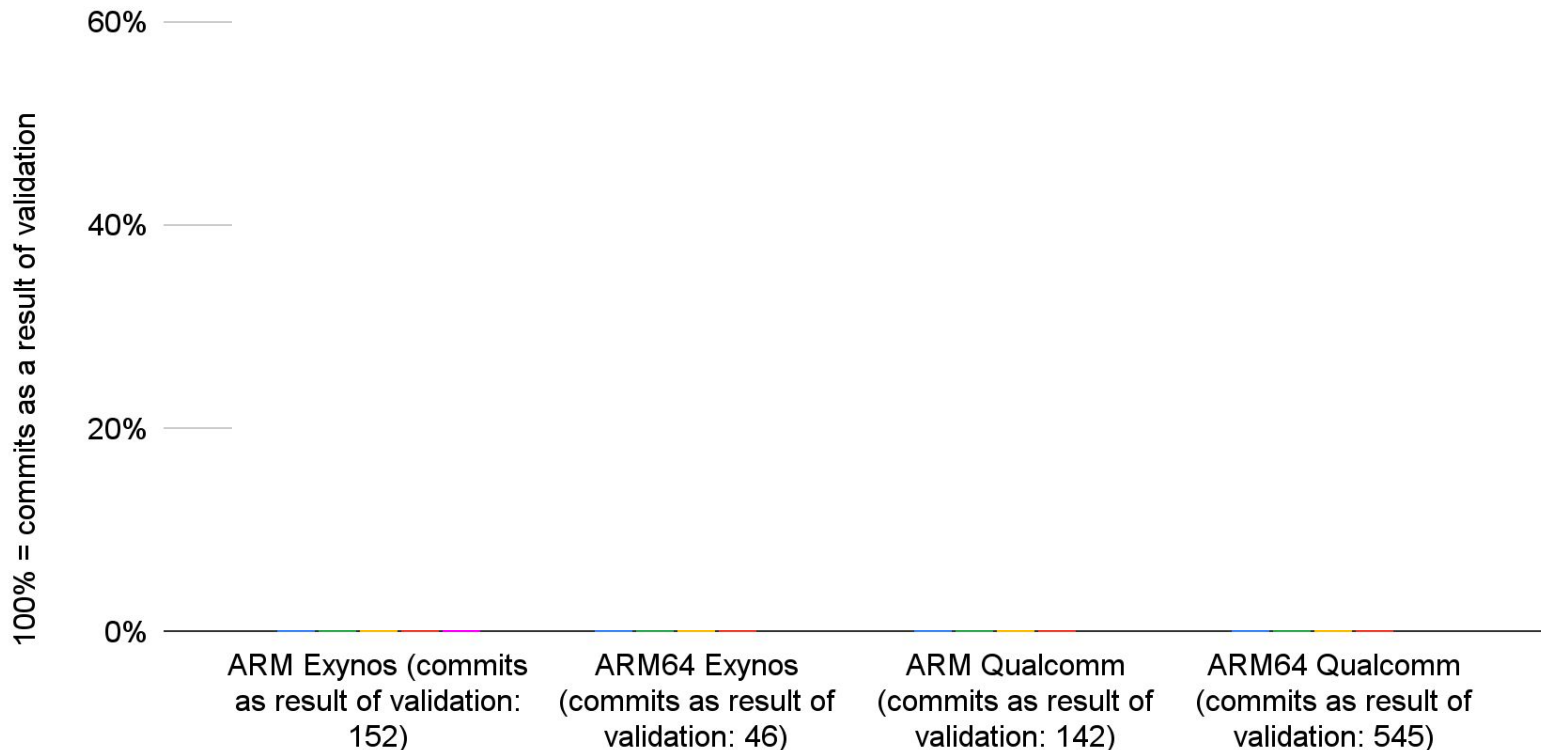


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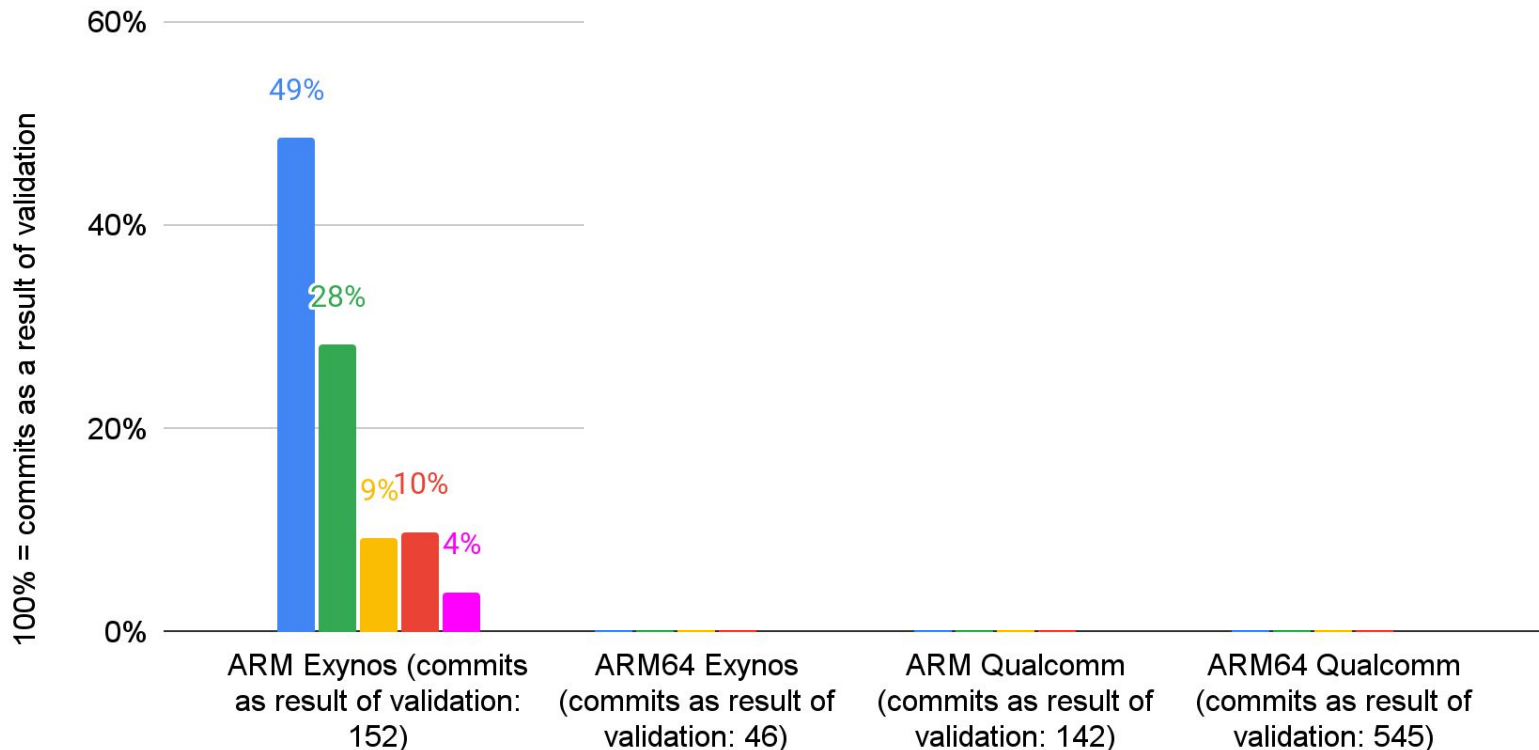
Classification of Commits as Result of Validation

■ Style ■ Improvement ■ Possible fix ■ Real fix ■ Future fix



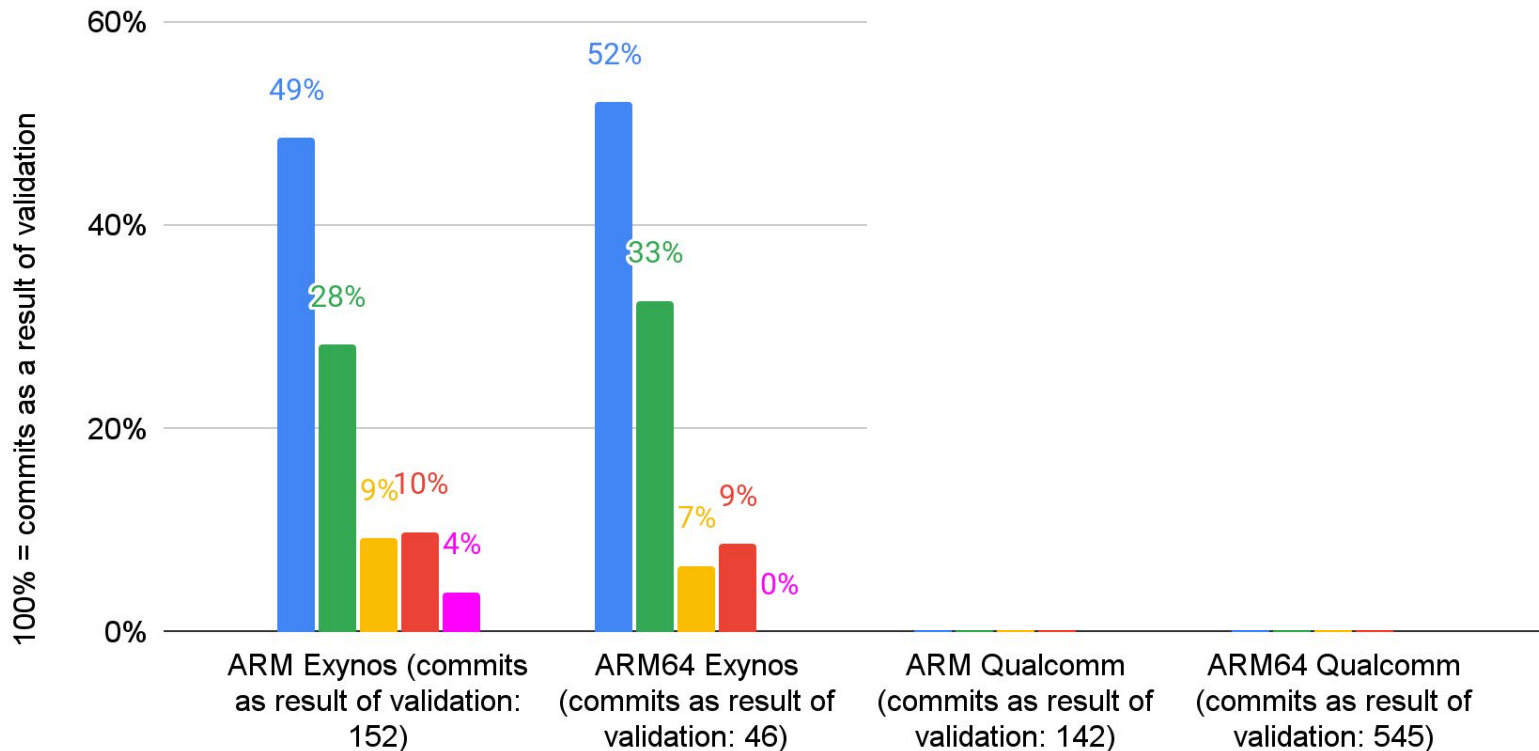
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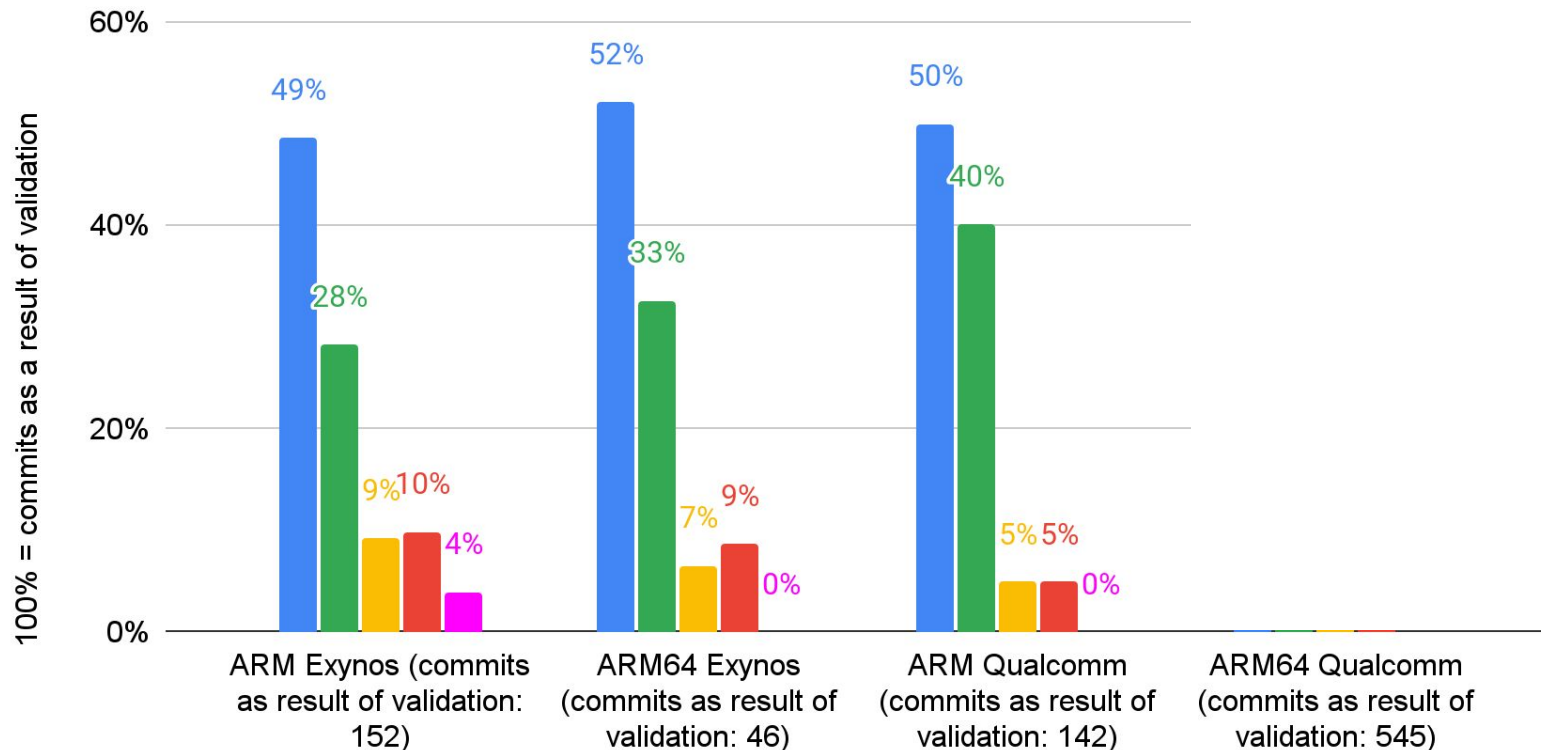
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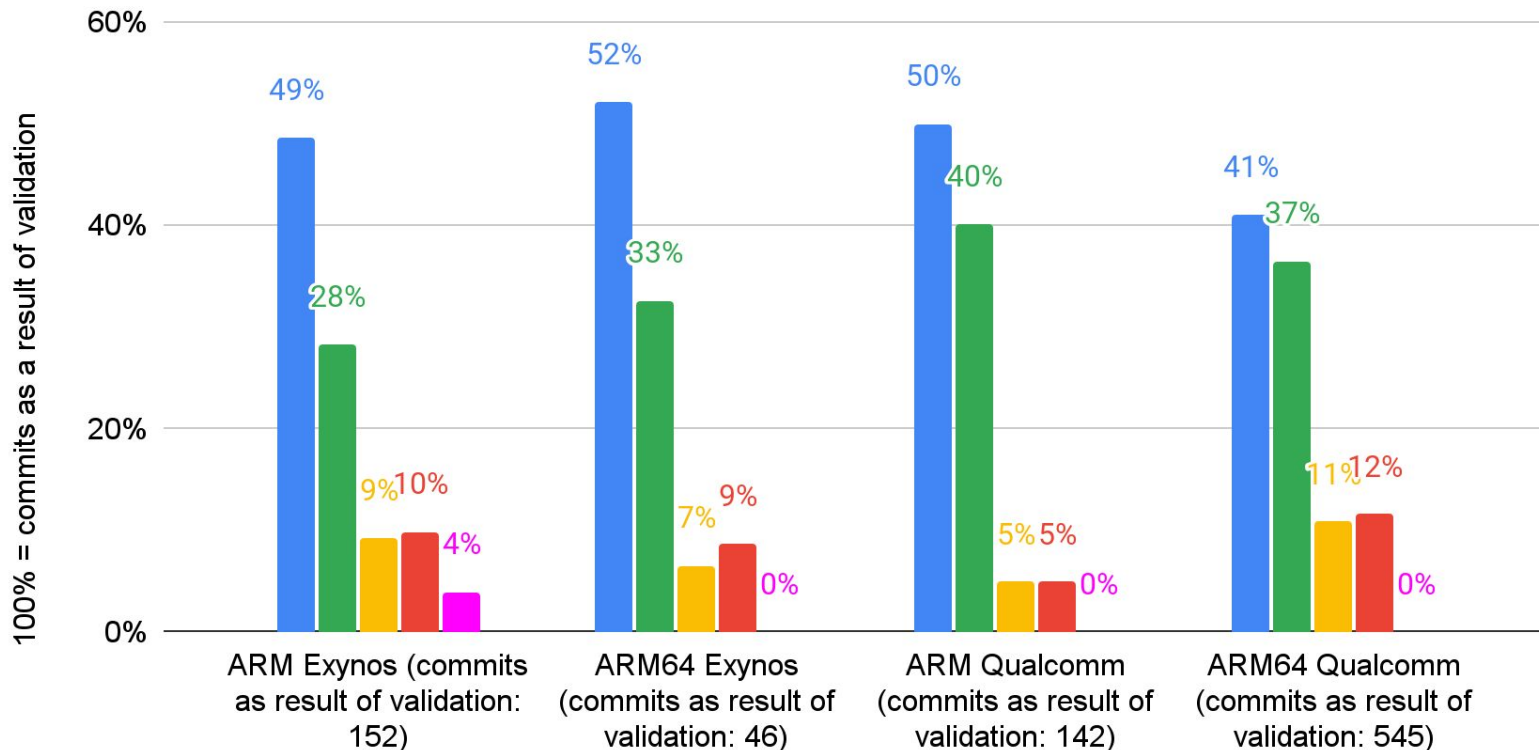
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- Unfortunately, on some platforms, new moles are coming as fast as I can whack them

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Visit www.linaro.org
Krzysztof Kozlowski
@krzk@social.kernel.org

